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Helispot Location and Construction

by James L. Murphy

FOREST SERVICE–U.S. DEPARTMENT OF AGRICULTURE

PACIFIC SOUTHWEST
FOREST AND RANGE
EXPERIMENT STATION
BERKELEY, CALIFORNIA

MISCELLANEOUS PAPER NO.31 —APRIL 1959

ACKNOWLEDGMENTS

To J. Whitney Floyd and other personnel of Utah State University, College of Forest, Range, and Wildlife Management, for guidance and help in the preparation of this report under the terms of a cooperative agreement with the Pacific Southwest Forest and Range Experiment Station.

To the following pilots for their technical advice:

Lynn Roberts
Roberts Flying Service
Boise, Idaho

Fred H. Bowen
Southwest Helicopters
Los Angeles, California

Bill Hartley
Cal. Rotors, Inc.
Pasadena, California

Lee Baxter
formerly of International Helicopters
Torrance, California

HELISPOT LOCATION AND CONSTRUCTION

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Miscellaneous Paper No. 31

April 1959

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION

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HELISPOT LOCATION AND CONSTRUCTION

By James L. Murphy[1]

SOME BASIC CONSIDERATIONS

"You cut trees, clear brush, dig out rocks, end up with a cleared area big enough to park a B-25 in—and a puny helicopter can't land in it. What does the pilot want, anyway?"

Unfortunately, a lot of men find themselves in this sort of predicament after working on a helicopter landing area. "What does he want, anyway?" is a good question. "Why does he want it?" is a better question. The answer requires an understanding of how a helicopter flies and what "density altitude" means.

How a Helicopter Flies

Helicopters are called "rotary-winged" aircraft. The overhead rotor does the job of a "fixed" wing on an airplane and also propels the aircraft. The tail rotor counteracts the torque effect of the spinning overhead rotor and stabilizes the aircraft. When a helicopter gets ready to take off, the pilot increases the power until the overhead rotor reaches 3,100 revolutions per minute. This is the power and r.p.m. needed to "lift" the dead weight of the ship. Each half of the blade can be tipped, or, in other words, the pitch of the blades can be changed. The pilot controls the pitch from the "stick" in his left hand. When he increases the pitch, the blades "bite" air, driving it against the ground. Of course, the air escapes from under the blades after it hits the ground, but the rotor is driving more air down than is escaping. As a result, a high density air cushion is built between the rotor blades and the ground.

The helicopter lifts itself up on this dense air cushion. Here, it may hover "in ground effect". To move forward, the pilot pushes the cyclic or joy stick forward, tipping the entire rotor blade path and "pushing" the helicopter toward flight, or thrust. The helicopter drops off the high density air cushion.

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[1] Formerly on the staff of the Division of Forest Fire Research, Pacific Southwest Forest and Range Experiment Station; present address: Payette National Forest, Council Ranger District, Council, Idaho.

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The next few seconds are the critical phase of the helicopter takeoff. It must achieve 18 miles per hour motion, relative to the free air, before the rotor acts as a wing and the helicopter flies. The important thing to remember, particularly when locating the helispots, is that the speed necessary to gain flight, or "translational lift," can be obtained by going forward or down, or both.

Once flying, the pilot maneuvers the helicopter by the two sticks and foot pedals. He synchronizes the two stick controls with the foot pedals controlling the tail rotor and thereby achieves direction.

When the helicopter prepares to land, the power and pitch of the blades are reduced. The "lift" power becomes less than the dead weight of the helicopter. The helicopter drops toward the ground, its direction of flight controlled by the tail rotor acting as a rudder. When the helicopter nears the ground, the pilot searches for his "ground effect," or that altitude at which the rotors start building the dense air cushion. When he finds this point, the pilot tips the helicopter back on its tail, a maneuver called "flaring". The flare allows him to increase the power and blade r.p.m. to a maximum. The helicopter then levels and settles to the ground.

Density Altitude

The rotary-winged helicopter depends upon the density of the air for flight. Everyone knows that as you go up in elevation, the air becomes "thinner," or less dense. Flight is easier and more dependable at sea level than it is at 7,000 feet in the mountains.

Everyone also knows that, as air temperature rises, the air becomes less dense. On a "90-degree in the shade" day, flying might be tough, but on a clear cold, 40-degree day, after a winter storm, flying conditions might be ideal.

So where does all this meteorology and physics fit into building a helispot? Let's take as an example a situation that is familiar to most field men that work with helicopters. A helicopter is operating out of a heliport located in an area you're well acquainted with. You know the elevation of the heliport is 5,000 feet above sea level; the map says so. A new pilot lands at the heliport. He asks the older pilot what the "altitude" is. The reply: "Around 8,000 feet." You step in and correct him. Both pilots then inform you: "5,000 feet is the pressure altitude. But we don't fly by pressure altitudes, we fly by density altitudes." What is density altitude? It is the pressure altitude corrected for the temperature at that moment at that spot. The air is thin enough to begin with at 5,000 feet pressure altitude, but on a 90-degree day the heat makes the air a lot thinner, or less dense.

The helicopter, then, is actually operating in free air that is as thin as you find it at 8,000 feet, the density altitude. (See Density Altitude Chart in appendix.)

HELIPORT-HELISPOT--WHICH IS WHICH?

Many people are confused by the term heliport and helispot. They seem to be used interchangeably. They are not the same, however,

A heliport is a base of operations for a helicopter; it may be a permanent base of operations called a base heliport or a semipermanent base, called a field heliport. A helispot is any temporary landing spot for helicopters. Helispots usually serve a specific, momentary need such as delivering water to the fireline or rescuing an injured man. A helispot consists of a landing area (the area that must be cleared to safely accommodate the helicopter while on the ground) and the takeoff and landing lanes. The landing area has within it the touchdown pad (that area on which the helicopter rests its skids while on the ground) and the safety area (the clear area outside the touchdown pad necessary for helicopter body and rotor clearance). Now that we've described a helispot, let's concentrate on locating and constructing them.

HELISPOT LOCATION AND CONSTRUCTION BY HAND CREWS

Any helicopter landing area has two basic needs:

1. Adequate takeoff and landing area.
2. Adequate flight paths in and out of the landing area.

Right away the question is raised, "What is meant by 'adequate'?" Let's see if we can be a little more explicit.

Ridge Helispot Locations

1. The best helispots are located on exposed knobs. This type of helispot gives a 360-degree choice of takeoff and landing direction. A landing area on a normal ridge generally gives only two choices of takeoff and landing direction, one side or the other.

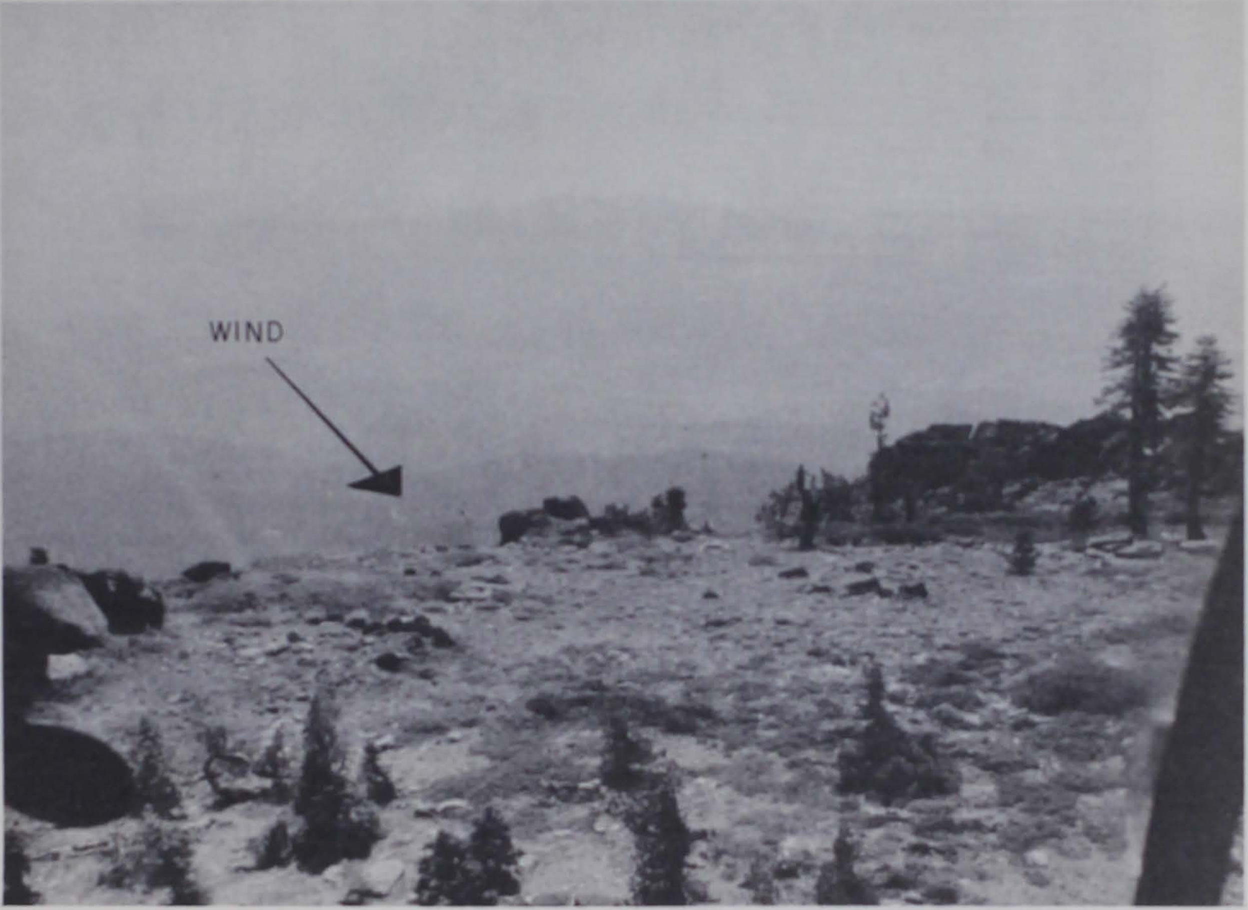
2. Always choose a spot where a dropoff is possible for helicopter takeoffs. The higher the elevation, the more important the dropoff becomes. A dropoff gives the helicopter a chance to parlay altitude lost into the necessary flying speed. Remember that if a helicopter has to make a vertical takeoff, it does so on power alone. At higher elevations it may take maximum power to lift vertically. This means that the helicopter can carry only a minimum payload. With a dropoff, the ship may use a lot less power and be able to carry a larger payload.

3. Always locate a helispot so that takeoffs and landings can be made into the prevailing wind. This also becomes more important with higher elevation. For each additional mile per hour of wind between 10 and 30 miles per hour, 15 additional pounds of gross weight may be added to the ship to get the same takeoff performance. A 20 mile per hour wind will allow the helicopter to carry 150 pounds more weight. Exposed knobs on main ridges again offer the best location.

Prevailing winds also help the helicopter gain flying speed. Taking off into a 10 mile per hour wind means that the helicopter must indicate only 8 miles per hour to achieve translational lift. Care must be taken when locating a helispot on a minor lateral ridge or near a bluff. Prevailing winds may be diverted by these features and wind directions may be variable and unpredictable. Under these conditions it is even more important that a wide choice of takeoff and landing direction be available. Caution must be used in locating helispots on lee sides of ridges because of downdrafts and eddies.

4. Always place a wind indicator on all helispots. Pilots may want to land on the spot when no one is available to indicate direction by other means. Throwing dirt is a good supplement to a wind flag as the dust will give a good indication of the wind velocity and of turbulence. Throwing dirt alone will suffice only if no other means of indicating direction is available.

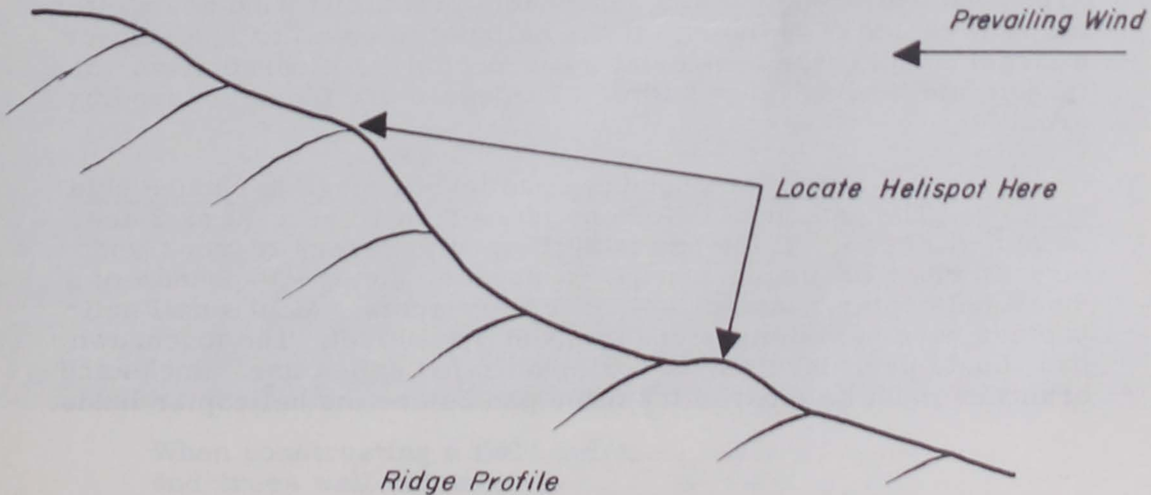
Locate a helispot on an exposed knob, if possible, with a 360° choice of takeoff and landing direction.



When locating helispots, try to pick natural areas that have a clear approach lane and a dropoff for takeoff into the prevailing wind.

Ridgetop Helispots

---on a Knob


Prevailing Wind
Locate Helispot Here

Ridge Profile

When locating a helispot in timbered country, look for naturally cleared areas offering a minimum resistance to construction.

Ridgetop Helispot Construction

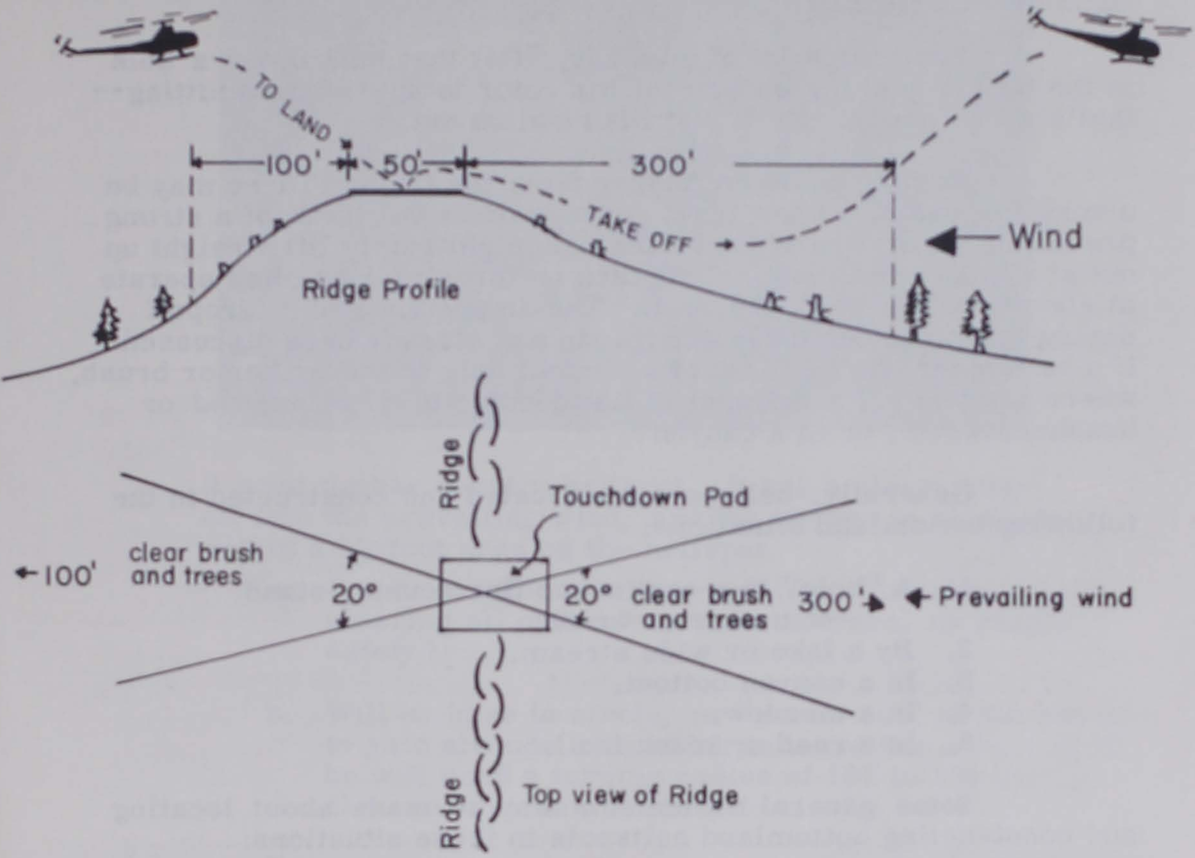
1. Remove all brush and trees within a 50-foot diameter safety circle around the landing area. Most small helicopters have an overall length of 40-42 feet. The diameter of the rotor blades is 35 feet. A 50-foot diameter area will give a good safety margin.

2. Clear brush and trees well below the level of the landing area. The helicopter needs a path to settle into when taking off. At elevations above 5,000 feet, the helicopter may need 200 to 300 feet to lift above the level of the helispot. An exposed knob with a natural dropoff into a dependable prevailing wind again offers the best choice of helispot. If the helispot is on a flat ridgetop or a larger saddle, the brush and trees should be cleared from the takeoff and landing lanes within a 20-degree arc from the landing area.

3. Make the touchdown pad level enough to reduce skid rocking. The pad should slope no more than 10 percent or 2 feet in 20 feet of pad. If the pad is built up with layers of rock and dirt, it must be stable enough to support the 2,400 pounds of a small helicopter. Avoid soft or crusty spots. Most small helicopters have skid dimensions of about 8 x 10 feet. The touchdown pad should be at least 15-20 feet square for safest use. Rocks and branches must be cleared from the pad before the helicopter lands.

RIDGETOP HELISPOTS

---on a Flat Ridge or saddle above 5,000 feet elevation


TO LAND
100'
50'
300'
TAKE OFF
Wind
Ridge Profile
Ridge
Touchdown Pad
100'
clear brush and trees
20°
20°
clear brush and trees
300'
Prevailing wind
Ridge
Top view of Ridge

When constructing a field helispot, clear all brush and trees well below the level of the landing area.

Bottomland Helispots

You hear a lot of men say, "Get that helicopter a hole in the timber just big enough for his rotor to spin without hitting--that's all he needs. He'll just lift right on out."

Nothing could be further from the truth. There may be a very few cases, at sea level perhaps or in the teeth of a strong prevailing wind, where the helicopter might safely lift straight up out of a hole. But most helicopters on forestry jobs often operate at elevations above 5,000 feet. The importance of a dropoff during takeoff under these conditions has already been discussed. If a helicopter can't lift out of a 40-foot hole in the timber or brush, where can you put a helispot in flat country that is timbered or brush-covered--or in a canyon?

Generally, helispots are located and constructed in the following bottomland situations:

1. A "hole" in a continuous flat-country stand of timber or brush.
2. By a lake or wide stream.
3. In a canyon bottom.
4. In a meadow.
5. In a road or truck trail.

Some general statements may be made about locating and constructing bottomland helispots in these situations:

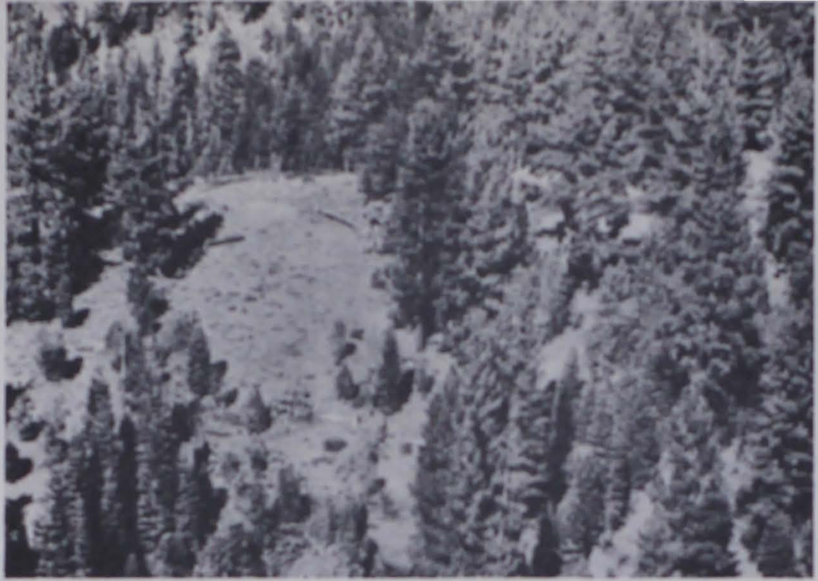
1. A truly vertical takeoff should not be considered safe at any elevation. Remember that the small helicopter must be at least 300 feet above the ground in order to auto-rotate or "glide" back to the ground in the event of engine failure. If the ship is less than 300 feet above the ground, it will drop like a rock. (See "The Deadman's Curve," in appendix.)

2. A vertical takeoff should never be depended upon under any circumstances when the helicopter is operating above 5,000 feet elevation.

3. Be sure the takeoff path is into the prevailing wind. Avoid "dead air" spots such as deep holes or areas on lee sides of ridges.

4. The best and safest takeoff path in a bottomland situation would be 300 feet long, slightly downhill with a good line of sight. The helicopter should be flying by the time he travels this distance.

5. Be sure the helicopter has some place to go when he gains forward flight at the end of this 300 foot takeoff path.



A good timber country helispot. It has a clear dropoff into the prevailing wind, and the timber is cleared within a 50-foot area on the helispot.

a. Can he continue "on and up" from his takeoff path, clearing all obstacles, such as trees, or ridges safely?

b. Will he have to circle, or "screw out" of the helispot to gain altitude with which to leave the area? If so, he will need a turning radius of 100 to 150 feet of cleared area within which to circle.

Here are some specific hints about locating helispots in four bottomland situations:

Lakes or wide streams.--Water furnishes a good ground-effect base. Remember that the helicopter will need at least 300 feet of water over which to gain flying speed. Also the ship will need a safe touchdown pad on the shore from which to operate.

Canyon bottoms.--Beware of "dead-air" holes. Be sure the canyon does not have a downdraft from one of the neighboring ridges. If the canyon is deep, the helicopter will need a long forward run to pull out of the canyon or an extra wide spot in the canyon within which he can circle safely.

Meadows.--Beware of meadows with high grass. The grass will tend to dissipate helicopter ground cushions. High grass may also hide rocks, logs, or swampy areas.

Roads or truck trails.--Try to pick turnouts or parking areas that might have some dropoff. If there are no dropoff areas available, be sure the helicopter has plenty of takeoff distance available down the road. Stay clear of heavily used roads or truck trails unless in an emergency, or unless traffic control has been previously arranged.

USING TRACTORS IN HELISPOT CONSTRUCTION

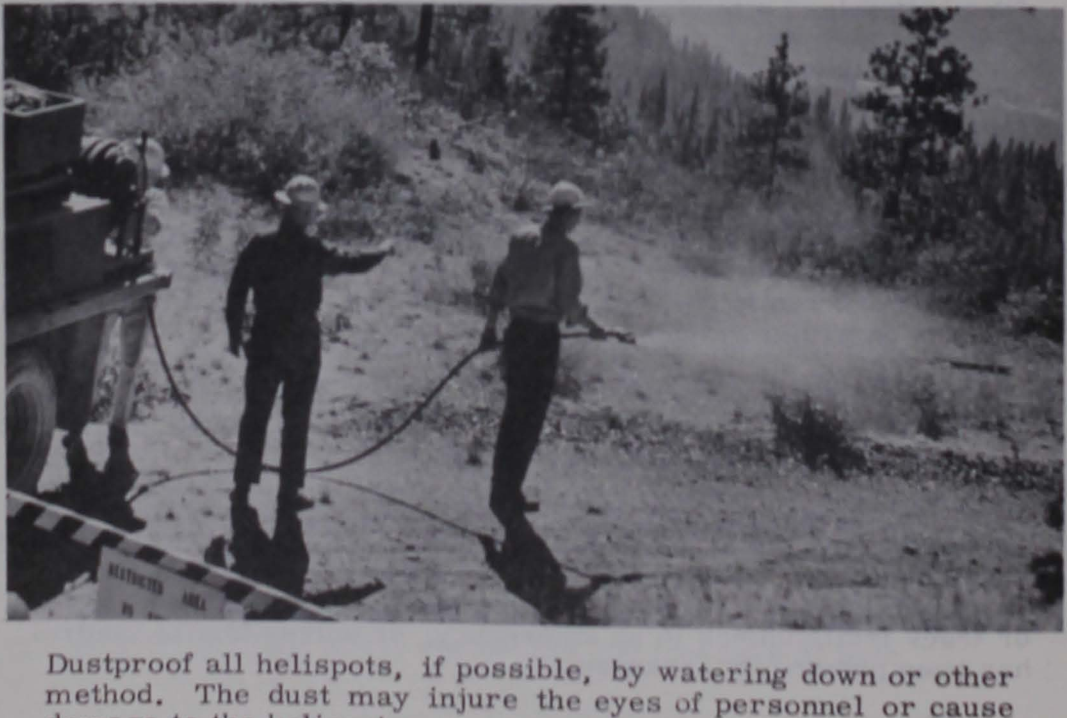
Many helispots may be constructed by tractors on fires or on timber sale contract projects. The fundamental requirements of field helispots are about the same whether constructed by hand crews or tractors, but a few added precautions need to be remembered when landing areas are constructed by tractors:

1. Tractors often work near developed areas. Power lines and telephone lines may be present. Remember that pilots ordinarily can only see the poles--they rarely can see the lines. Avoid this situation.

2. Tractors may dislodge large rocks. These must be removed and the area smoothed before the helicopter can land.

3. Occasionally a tractor can construct an excellent helispot but is unable to remove tall brush and trees on the adjacent slopes. Hand crews must work with the tractor to remove the growth before the helicopter lands.

4. Tractor work tears up the soil in such a manner that dust and flying pebbles constitute a menace to both the pilot and the helicopter engine during takeoffs and landings. The eyes of any nearby person may be endangered also. If the helispot is to be used soon after construction and before the winter's rain, arrangements should be made to dustproof the area by wetting down, or, if possible, by oiling.



Dustproof all helispots, if possible, by watering down or other method. The dust may injure the eyes of personnel or cause damage to the helicopter.

HELICOPTER LANDING APPROACHES

Most of the discussion thus far has been about helicopter takeoffs. But what about helicopter landing approach paths? Generally the landing is nowhere near as critical as the takeoff. The helicopter already has his altitude and/or flying speed. He will not have to drop below the level of the helispot in landing. However, a truly vertical landing cannot be depended upon under normal conditions. Therefore, an approach path free of obstructions will be necessary.

If the helispot is on a point or a knob, clear any trees or brush that project above the level of the landing area. The clearing will allow the helicopter to make a safe "flare out" landing.

If the helispot is on a flat ridgetop or in a saddle, clear brush and trees within a 20-degree arc from the landing area. Remember that the helicopter lands into the prevailing wind.

If you are near a possible landing area and see a helicopter circling above you, the chances are he may want to land. Always give him the wind direction:

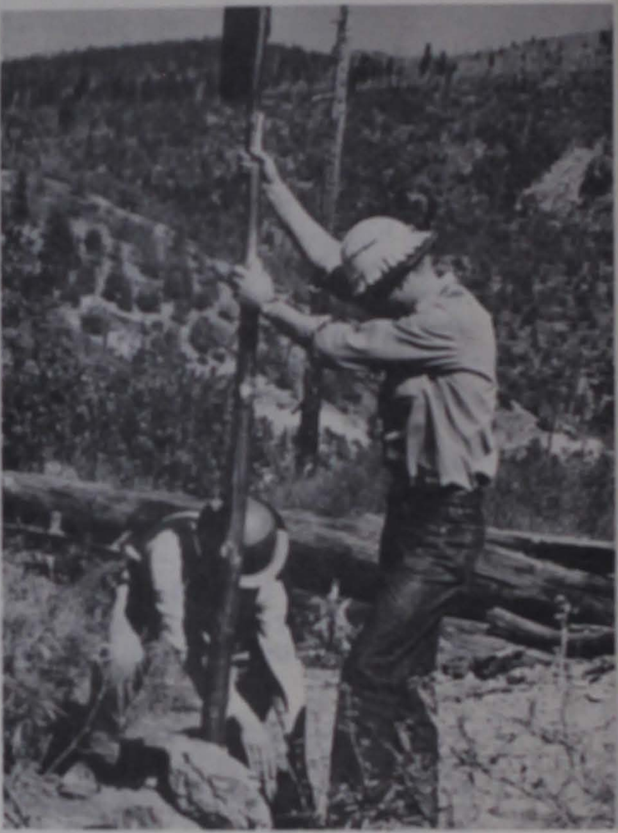
1. Place white, yellow or orange flagging on an exposed, visible spot. Don't place a high pole in his landing or takeoff lane.

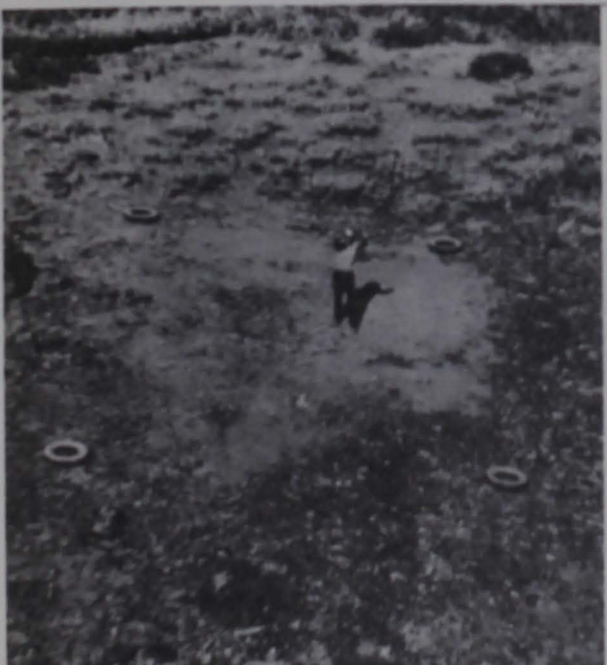
2. Throw dirt--a lot, and high.

3. Stand with your back to the wind, both arms extended in front of you, pointing with the wind and indicating to the pilot, "Land here."

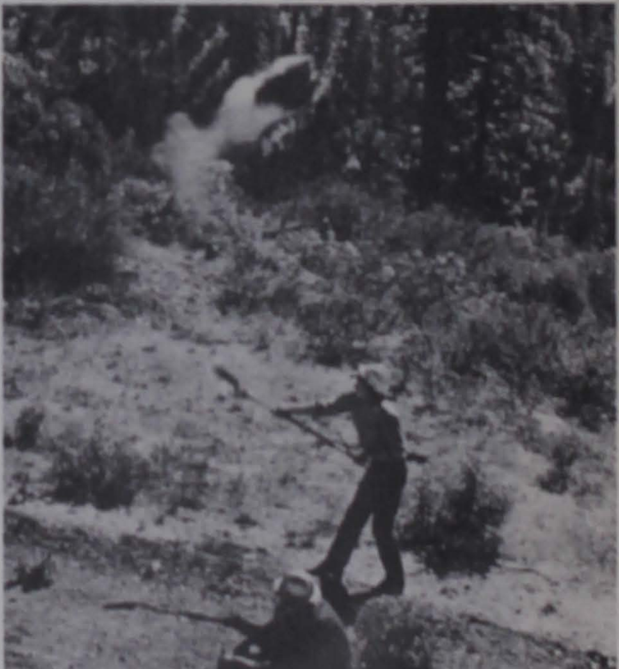
At bottomland helispots the question may arise: "Where does the approach path end and the takeoff path begin? If the helicopter needs 300 feet of clear takeoff area, do I have to add another 100 feet for clear landing area also?" Generally, the 300 feet will be plenty. The helicopter may land into the prevailing wind near the end of the takeoff path. However, when the pilot gets ready to take off, he can hop the empty ship back to the beginning of the takeoff lane, load it, and use the entire 300 feet to gain flying speed. Extra clearance for landing paths, then, is not usually necessary.

Provide a permanent wind flag if possible. Use a smooth bark pole or remove the bark so that the flag will not hang up.





Stand with your back to the wind. Extend your arms toward the helicopter indicating "land here".

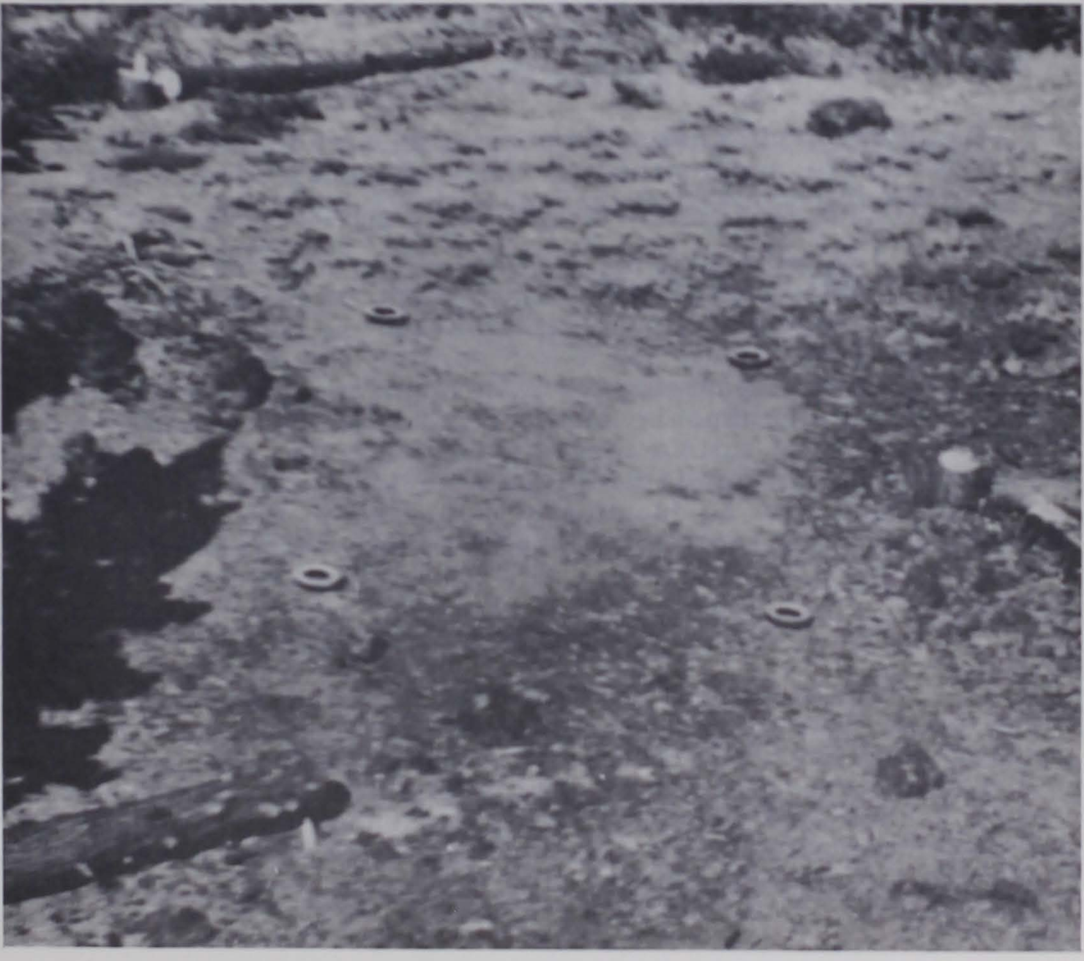


Throw dirt--a lot, and high. Dust will help to tell the pilot the wind velocity and to warn him of turbulence.

HELISPOT MARKING

Many men spend a lot of man hours constructing a helispot, particularly in timbered country, only to find that it is difficult--often impossible--to find again. All helispots should be marked so that they are readily visible from the air. An old tire, painted yellow and anchored securely, makes a good marker. A galvanized metal triangle may be fastened over the tire to make it more visible. A large identification number may then be painted on the triangle. Four rocks, or stumps, each located near one corner of the landing area, may be sprayed with orange or yellow paint to delineate the area.

Field experience indicates that recreationists may disturb the tire locations unless they are labeled as government property. Anchoring the tires firmly will also discourage their removal. Where the helispot is likely to be used often, a cement slab may be justified in lieu of the less permanent tires.



Old tires painted high visibility yellow or orange, help to make the landing area visible from the air.

HELISPOT MAPPING AND RECORDING

No two helispots will have the same conditions or topography, adjacent cover, wind, or associated hazards. For purpose of future reference, field men have found that helispot recording, both by description and on a map, helps to orient pilots intending to land on the helispots.

Field recording. --All helispots should be recorded on some type of helispot information form. (See suggested helispot information form in appendix.) The forms should be filled out at the helispot after it is finished and before leaving the area. Supply all the information you can, especially hazard information.

Office filing. --Three active helispot files should be maintained:

1. Currently usable helispots approved by the pilot.
2. Completed helispots requiring maintenance to become safe or currently usable.
3. Planned helispot locations, to be constructed.

> Important: If a helispot becomes unsafe to use because of needed maintenance or other reasons, remove that helispot record from the currently usable file.

Helispot mapping. --When a fire or other project requiring a helicopter occurs, the project is usually located on a map. If available helispots are marked on that map, the possibilities of immediate helicopter service can readily be seen. Colored circles may obscure map detail and may be difficult to remove if a helispot becomes unsafe. Numbered map pins have been found very satisfactory for this purpose. The heads stand off the map, leaving all detail visible, and they are readily removed. The helispot may be identically numbered in the field, in the description files, and on the map, for ready reference.

IF IN DOUBT, ASK THE PILOT

It is difficult to write about locating and constructing helispots. Every helispot is located and constructed under different conditions. To list a set of instructions covering all conditions is impossible. It is hoped that the basic fundamentals along with the few general observations presented here will help the beginner. Maybe the most helpful suggestion, after all, might be simply: "If in doubt, ask the pilot!"

APPENDIX

HELISPOT LOCATION, CONSTRUCTION CHECKLIST

Important: Use this checklist twice.

1. Before you begin work on helispot
2. After you think you have finished construction of helispot.

BEFORE-AFTER CONSTRUCTION

☐ Can takeoffs and landings be made into the prevailing wind?

☐ Are takeoff and landing lanes cleared well below level of landing pad?

☐ If helispot is on a ridge or knob, has helispot a clear drop-off for takeoff?

☐ Is helispot landing area at least 50 feet in diameter for rotor clearance?

☐ Is touchdown pad at least 15 feet square?

☐ Is touchdown pad level and firm?

☐ Is touchdown pad clear of rocks, brush and stumps?

IF HELISPOT IS IN A MEADOW; BY A LAKE; ON FLAT GROUND

☐ Has helicopter at least 300 feet of clear area to achieve forward flight?

☐ Is area at least 250 feet wide so that helicopter can circle or "screw" out?

BEFORE LEAVING HELISPOT

☐ Have you placed a wind indicator on helispot?

☐ Have you marked helispot so it is visible from air?

☐ Have you filled out Helispot Information Form completely?

HELISPOT INFORMATION FORM

Helispot Number ______________ Elevation ______________

Location: 1/4 Sec. ______ Section ______ T. ______ R. ______

Location by landmark ______________________________

Topography:
- Point ☐
- Knob ☐
- Ridge ☐
- Saddle ☐
- Meadow ☐
- Flat ☐

Adjacent cover type:
- Timber ☐
- Brush ☐
- Grass ☐
- Barren ☐

Prevailing wind direction ______________________________

Most reliable approach direction ______________________________

Most reliable takeoff direction ______________________________

Density altitude, average summer afternoon ______________

Hazards (describe): ______________________________

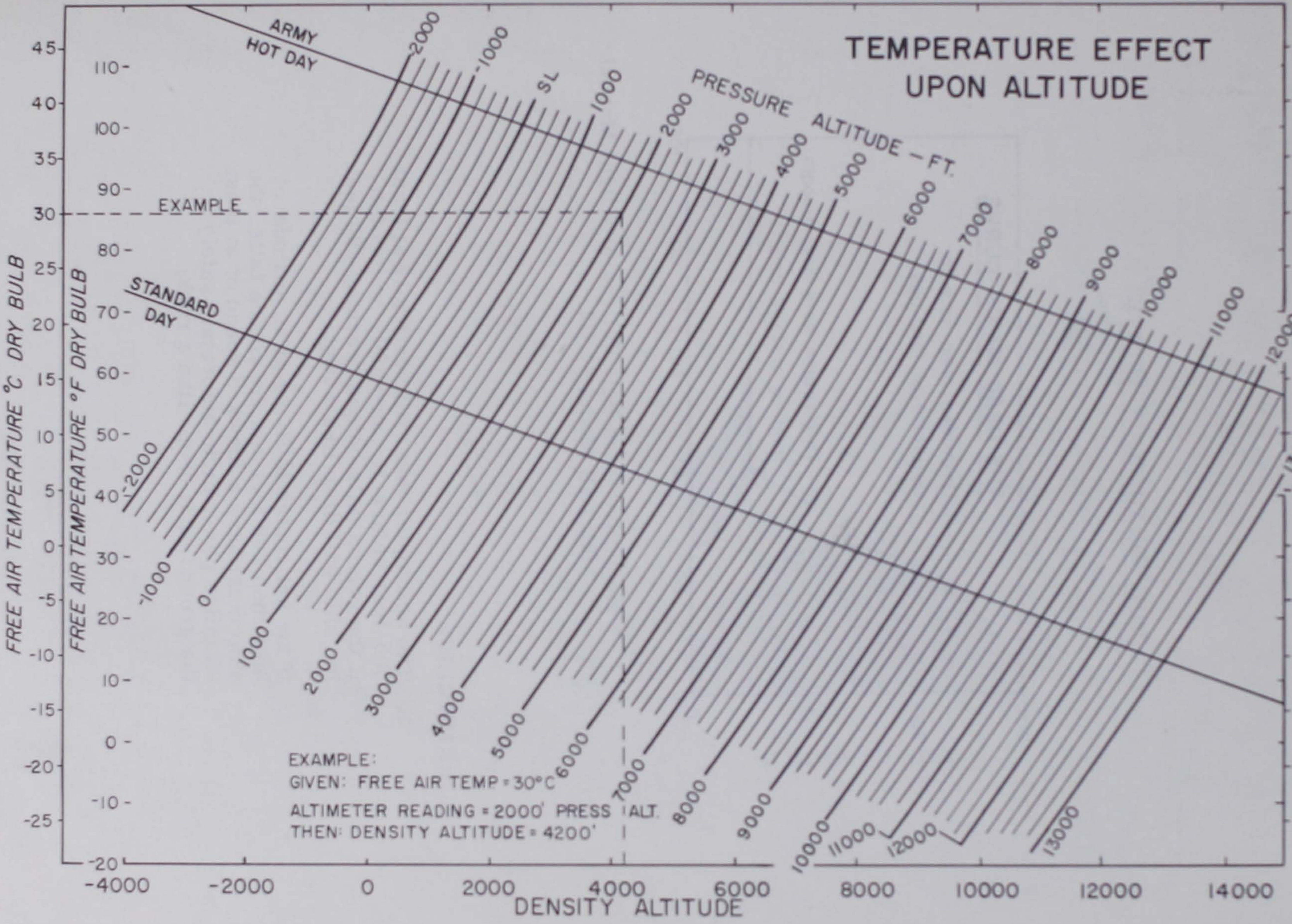
____

____

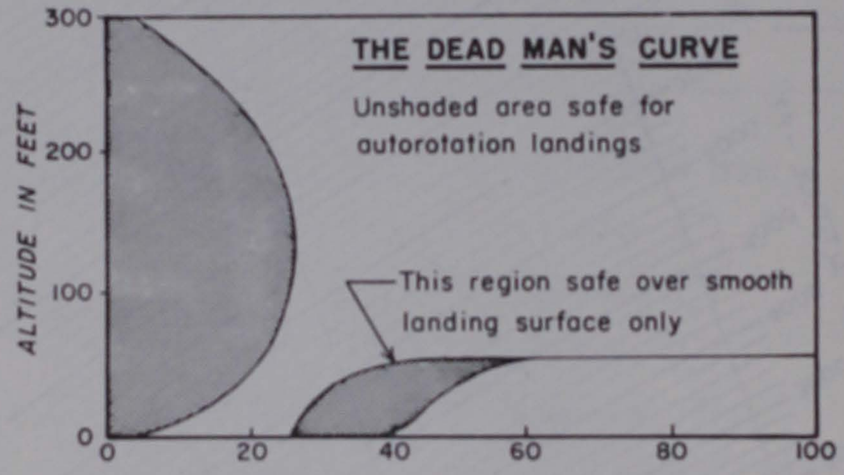
Remarks: ______________________________________

____

____


TEMPERATURE EFFECT
UPON ALTITUDE
PRESSURE ALTITUDE – FT.
ARMY HOT DAY
STANDARD DAY
EXAMPLE
FREE AIR TEMPERATURE °C DRY BULB
FREE AIR TEMPERATURE °F DRY BULB
DENSITY ALTITUDE
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-4000
-2000
0
2000
4000
6000
8000
10000
12000
14000
-2000
-1000
SL
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
EXAMPLE:
GIVEN: FREE AIR TEMP = 30°C
ALTIMETER READING = 2000' PRESS ALT.
THEN: DENSITY ALTITUDE = 4200'

THE "DEADMAN'S" CURVE *



* Reprinted from Bell Helicopter Flight Manual for Bell Model 47 G2.

REMEMBER:

1. The helicopter must lift vertically at least 300 feet before it can safely autorotate. If the engine fails before reaching 300 feet, the ship will drop like a rock.

2. If the helicopter is flying at an altitude of less than 200 feet and the engine fails, the ship must have a forward speed of at least 28 miles per hour to autorotate safely to the ground or it drops like a rock.

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THE HELIJUMP-- The Research and Development of the Helicopter Hover Jump Technique.

by James L. Murphy

FOREST SERVICE-U.S. DEPARTMENT OF AGRICULTURE

PACIFIC SOUTHWEST
FOREST AND RANGE
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MISCELLANEOUS PAPER NO. 32 – APRIL 1959

THE HELIJUMP--THE RESEARCH AND DEVELOPMENT OF THE HELICOPTER HOVER-JUMP TECHNIQUE

By James L. Murphy [1]

Miscellaneous Paper No. 32

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U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION

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THE HELIJUMP--THE RESEARCH AND DEVELOPMENT OF THE HELICOPTER HOVER-JUMP TECHNIQUE

By James L. Murphy

"The fire's only a spot--I could catch it if I could hit it in the next few minutes--but this helicopter can't land in that brush." This kind of predicament faced many firemen in the early days of helicopter fire reconnaissance (1), when a crew hiking into the fire usually couldn't hope to reach it for hours. Soon the helicopter-firemen started thinking about jumping--"if the helicopter can hover a few feet off the ground, I'll just step out on the skid and jump." Many of these hover-jumps were actually done (1, 2), but the firemen were flirting with serious injury. In 1949, the Forest Service tightened down on its helicopter operating policy--no jumping was the order (3).

By 1953, the helicopter as a forest fire-fighting tool was definitely "in". However, it would be years before adequate helispot coverage could be developed in inaccessible country. There was a definite place for the hover-jump in helicopter operations if the jump could be done safely. This required a proved jump technique, a protective suit, and trained personnel and pilots. A "Helishot" [2] crew organized on the Angeles National Forest in 1954 (4) showed that safe hover-jumping by a team of helicopter specialists could be done.

In 1955 Project Helitack [3] was begun. The main objective of Helitack was the integration of helicopters into forest fire suppression (5). Helitack included as one of its specific objectives the organization and training of "Helitack crews," or crews of helicopter specialists. The work included development of safe guidelines for the helicopter hover-jump, or "helijump".

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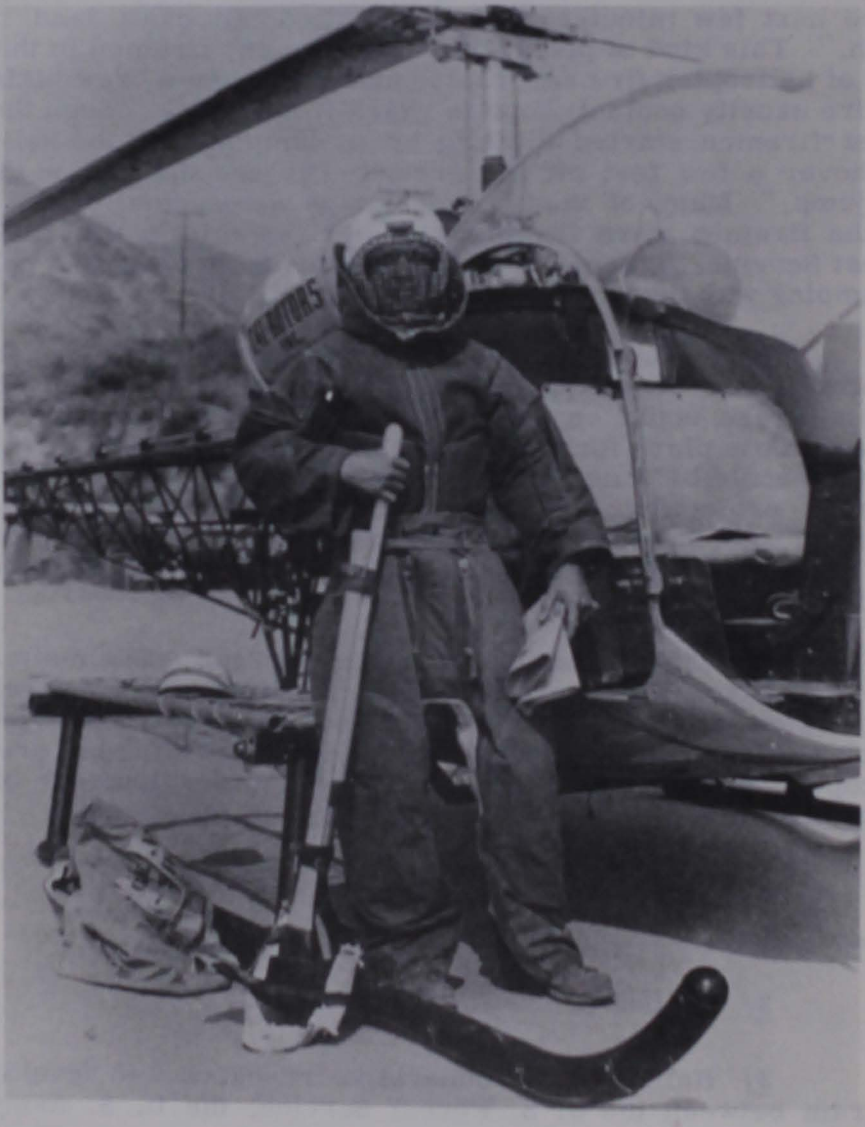
[2] Helishot: "helicopter hot-shot".

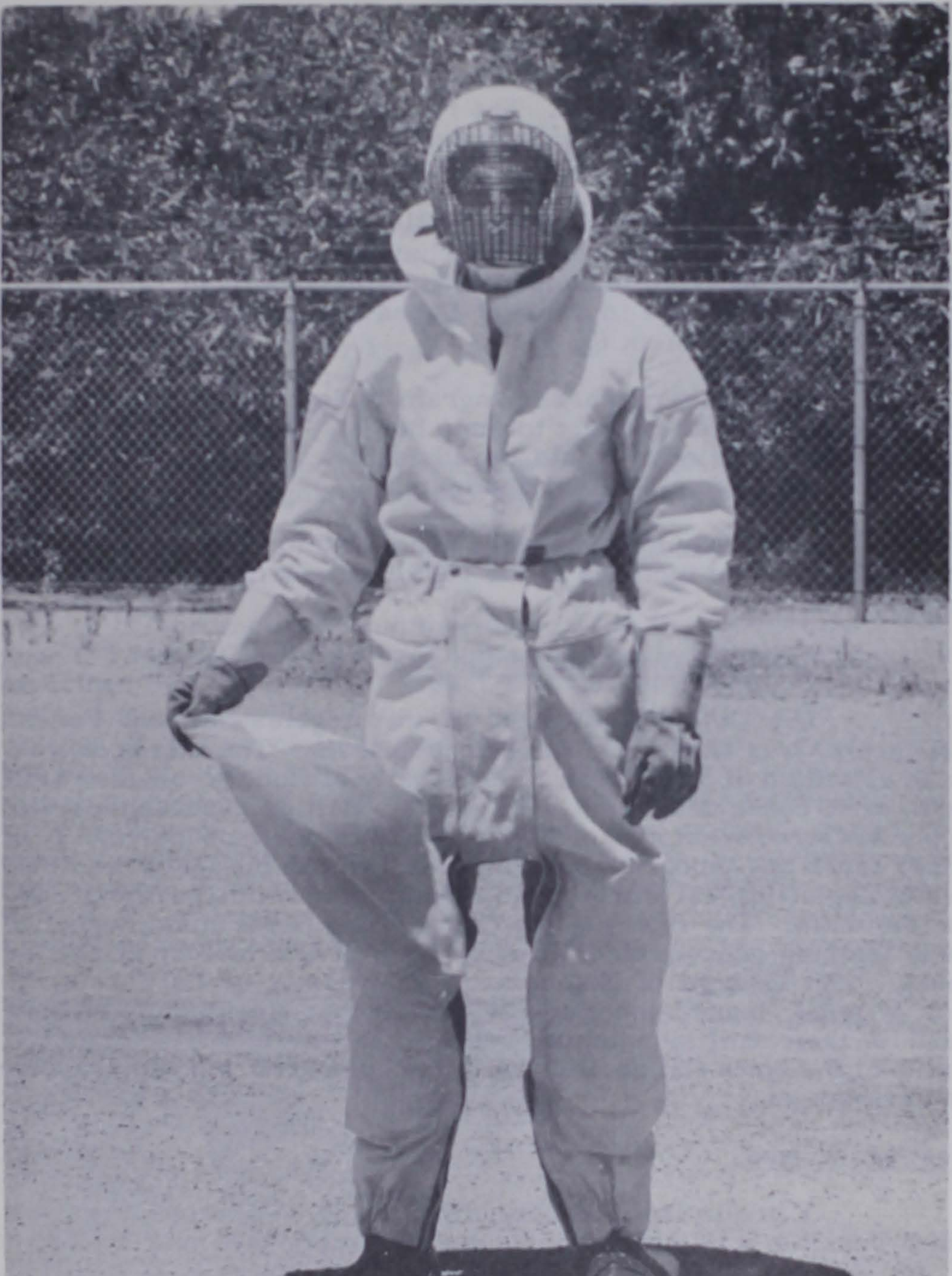
[3] Helitack is a cooperative research and development program between the U. S. Forest Service, the U. S. Army, and the California Division of Forestry.

DEVELOPMENT OF THE HELIJUMP TECHNIQUE

In 1954 and again in 1956 Helitack crews on the Angeles National Forest worked with contract helicopter pilots and developed a preliminary helijump technique (4, 6, 7). But more intensive studies were necessary before specific guidelines could be set up. Also, a coverall-type protective suit was developed in 1954 by the Angeles Forest Helitack crew (4, 7). Use of the suit showed it had many limitations. The expert guidance of the Missoula Aerial Equipment Development Center was enlisted to help solve the many technical problems of protective garment design and manufacture, resulting in a revised suit in early 1958.



A coverall-type helijump protective suit was developed in 1954 by the Angeles forest Helitack crew.



The guidance of the Missoula Aerial Equipment Development Center was enlisted to help develop and manufacture the 1958 model helijump suit.

By early summer, 1957, the preliminary helijump technique and the protective suit were ready for field testing. Forest Service Safety Officer Seth Jackson reviewed the Helitack crew program in June of that year. The recommendations that he made set the pattern for future Helitack developments. Mr. Jackson's recommendations were:

1. That crew training would be necessary to safely orient field personnel in Helitack techniques. The 1957 Helitack crew training program included 300 fire fighters from 13 national forests, the California Division of Forestry, and the Los Angeles County Fire Department (8, 9).

2. That a research program to determine specific helijump guidelines with respect to jump heights, helicopter speeds, cover types and slopes would be advisable. He suggested that movable dummies be used for the tests.

The helijump tests were scheduled for early 1958. Test results were to be included in the 1958 Helitack crew training program.

Helijump Guidelines--the 1958 Test Program

The Chilao Flats area of the Angeles National Forest, California, was chosen for the helijump tests. The test area was at an elevation of 5,300 feet. The density altitude[4] on the days tests were conducted was 7,500 feet, a condition representative of many western forest areas. Chilao Flats offered a wide variety of cover types and topographical variations within the test area. The prevailing southwest wind varied from 5 to 10 miles per hour during the tests. The Los Angeles County Fire Department furnished their training officer, chief pilot, and a Bell G-2 helicopter for the tests. The College of Engineering, University of California, at Los Angeles, loaned the Forest Service two electronic dummies used in their collision injury research program. The Angeles National Forest's Chilao Helitack crew provided technical advice and assistance.

Test Objectives

A preliminary examination of the test procedures and their possible implications indicated that more than just helijump guidelines might be expected from the tests. The final aims of the helijump tests were:

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[4] Density altitude is pressure altitude corrected for temperature.

1. To test the safety features of the current helijump protective suit under various conditions of cover type and terrain.

2. To establish guidelines for a safe helijump with respect to:

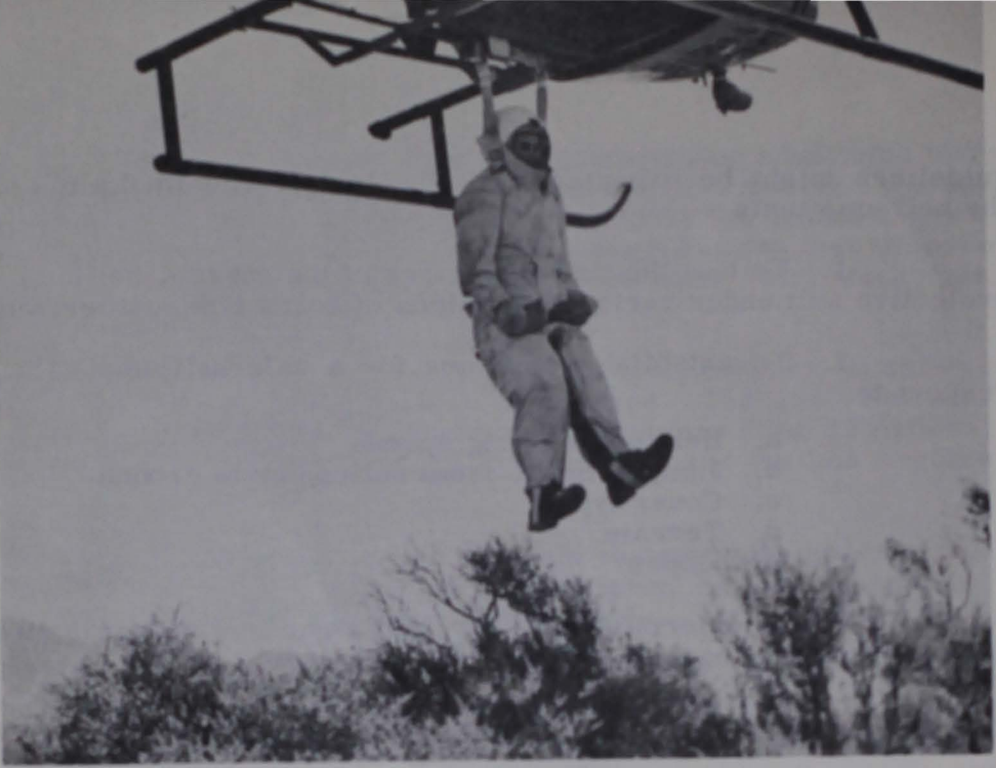
   a. Helicopter flying speeds
   b. Jump heights, from helicopter to ground
   c. Cover types
   d. Terrain
   e. Slopes

3. To determine whether test results would indicate any necessary changes in the helijump technique.

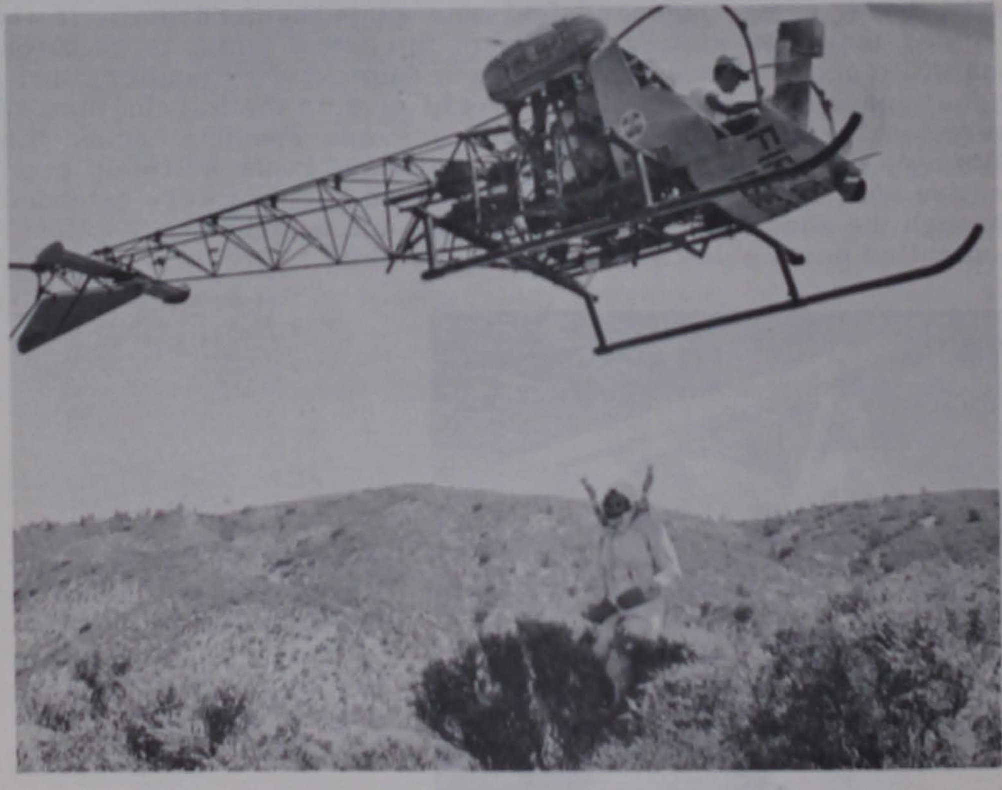
Test Procedure

The movable dummy chosen for the tests was a 175 pound, 5 foot 10 inch "95 Profile" mannequin. UCLA engineers explained that "95 Profile" meant that the movement of the dummy's body, head, arms, legs and feet was 95 percent normal. It was decided that slow motion movies of the actual jump, large black and white photos of the position of the dummy after landing, and visual inspection of each jump would give us the information we were looking for. A parachute harness was snapped around the dummy's body and the dummy was dressed in the helijump protective suit. The suspension straps of the harness were extended through the shoulders of the jump suit and attached to a pilot-controlled bomb shackle underneath the ship.

A 175 pound, 5-foot 10-inch dummy whose movements were 95 percent normal was dressed in the helijump protective suit for the tests.



The dummy was suspended from a pilot-controlled bomb shackle underneath the ship.



When the helicopter was over the jump spot, the pilot pressed the release button and the dummy dropped into the test plot.

The dummy was placed in the position a crewman should take after stepping off the helicopter skid during the helijump procedure. When the helicopter was over the jump spot, the pilot pressed the release button, and the dummy dropped into the test plot.

Twenty test plots were chosen in the experimental area. The test plots represented each of the following variables:

Cover types--

Manzanita (Arcotostaphylos sp.), light, medium, and heavy density

Chamise (Adenostoma sp.), light, medium, and heavy density

Scrub Oak (Quercus dumosa), light, medium, and heavy density

Coniferous (Pinus ponderosa), a seedling and sapling stand

Buckbrush or Buckthorn (Ceanothus sp.), a dense buckthorn field

Open terrain--

Grass covered

Litter covered (Primarily pine needles)

Dirt covered

Slope--

15 percent open and brush covered

30 percent open and brush covered

60 percent open and brush covered

Dummies were dropped into each of the test plots at two separate flying speeds: at zero, or hover, speed and at 5-10 miles per hour.

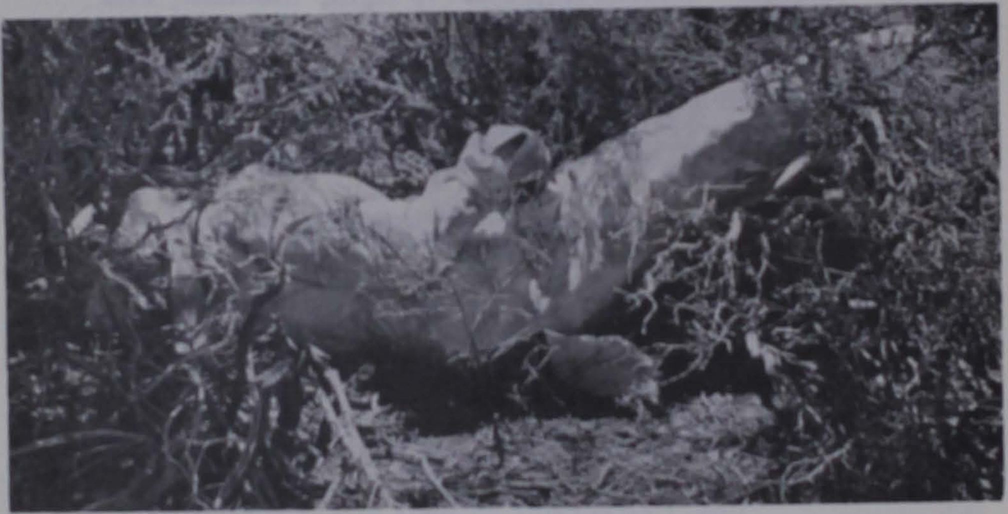
Because of the risk of damaging electronic controls in the dummy, the controls were removed from the dummy before the tests. To determine the maximum safe free fall distance for a human body, research results were obtained from tests conducted by the Aero Medical Laboratory, Wright Air Development Center, United States Air Force (10). These results indicated that 10 feet above the ground was the maximum safe jump height. All helijump tests were conducted within this height.

Results and Conclusions

The Helijump Suit

1. The felt padding on the helijump protective suit served two purposes; it was a shock absorber, but it was also an effective puncture-proofing material. In one instance, the felt padding furnished complete protection against a jagged piece of manzanita limb. Subsequent additions of felt padding to some areas of the helijump suit have made it much safer.

2. The fine mesh screen on the face mask is both necessary and effective. The dummy landed face down in fine brush and heavy litter on one jump without any indication of possible injury.



↑ The felt padding in the helijump suit prevented a jagged piece of broken manzanita from penetrating through to the body.

← The fine-mesh face mask completely protected the face when the dummy landed face down in fine brush and heavy litter.

A forward speed of 5-10 miles per hour helps the jumper settle naturally into the cushioning green limbs.

Flying Speeds

1. Zero flying speed, or a hover, is difficult to achieve or maintain, particularly when there is a wind.

2. When jumps were made into brush from flying speed of 5-10 miles per hour the slight forward speed helps the jumper settle naturally into the cushioning limbs.

3. A forward speed of 5-10 miles per hour over open ground aids the jumper in going into a simple roll with the direction of the ship. This observation was significant since a distinct hover cannot be depended upon.

4. Flying speeds over 10 miles per hour may prove dangerous in some situations. The speed would have a tendency to throw the jumper along the ground, rather than allow him to roll naturally. Possible injury could result from being thrown against rocks or heavy limbs.

Flying speeds over 10 miles per hour may tend to throw the jumper against heavy rocks or heavy limbs.

Cover Types

1. The average height of the helicopter skids above the tallest stems was 2 feet. Vegetation can be no taller than 8 feet to keep within the 10-foot jump height limit.

2. All three densities of manzanita--light, medium, and heavy--perforated the protective suit. In light and medium manzanita the perforations were caused by dead material of which there seemed to be an excessive amount. The green boughs in the light and medium densities were relatively resilient. In the heavy manzanita, the weight of the dummy sheared one of the heaviest brittle limbs. The jagged edge tore the suit, but the felt padding prevented a complete perforation. Slow motion movies later showed that as the dummy fell through the different cover types, the manzanita appeared as a stiffly vibrating picket fence while the other cover types bent as a wheatfield in a brisk wind.

3. Chamise, scrub oak, buckthorn, and coniferous reproduction stands under 10 feet in height proved to be resilient and shock-absorbing. Of these types, light to medium buckthorn and scrub oak patches offered the best jump cushion.

Light to medium buckthorn and scrub oak make good jump cushions.

4. The best cushioning effect in the deliquescent cover types was observed when the dummy was dropped to the outer edge of the individual brush clumps.

5. One patch of medium scrub oak contained an excessive amount of visible dead material. The green branches were very resilient under the dummy's weight. The dead limbs broke, producing sharp points. The brittle nature of dead material could be dangerous to the helijumper.

6. Three of the cover types tested--oak, chamise, and manzanita--were deliquescent species. Several times the dummy dropped into the middle of the brush clump feet first. A foot lodged in the stem junction and was held fast while the body fell away. A severe ankle sprain or break could have resulted.

7. Retrieving the dummy was difficult in the heavy oak and chamise stands and in buckthorn fields. A helijumper might have trouble freeing himself and departing from the jump spot in dense cover types.

A jumper might have trouble freeing himself and departing from the jump spot in dense cover types.

8. Tools dropped from the helicopter were hard to locate and retrieve in the dense cover types. Flagging the tools made them much easier to locate.

9. Dense cover, particularly buckthorn fields, may hide rocks or logs.

Open Ground

1. Grass-covered areas make good jump spots if the grass is not high enough to hide the logs or rocks.

2. Litter- and pine-needle-covered areas provided good jump spots.

3. Dirt surfaces were good if no large rocks were present. On one jump the dummy's foot struck a medium-sized rock and the entire leg collapsed unnaturally. A severe strain or sprain could have resulted.

Slopes

1. Several methods of helicopter approach to jump spots on slopes were tried. The safest method proved to be contouring the slope, with the jumper stepping out on the near-slope side.

2. The natural tendency of the dummy when landing on slopes was to fall backwards, or downhill, even though facing into the hill. When the dummy was placed in an exaggerated forward lean while landing, the tendency to fall over backwards was eliminated.

3. On open slopes less than 60 percent, the dummy fell forward, occasionally sliding a few feet downhill. On 60 percent slopes, however, nearly every jump resulted in the dummy sliding downhill a considerable distance.

4. On moderate slopes--15-30 percent, when the dummy was dropped between brush clumps, the clumps helped to check downhill sliding.

Clumps of vegetation on moderate slopes may keep the jumper from rolling.

5. Uneven ground on a 30 percent slope threw the dummy off balance when landing. Instead of falling naturally into the slope, the dummy twisted and plunged headlong down the hill.

6. A hidden rat's nest acted as a springboard during one jump into brush on a 60 percent slope. The dummy hit the nest and was catapulted down the hill.

7. Tools dropped into open slopes tended to roll downhill. Dropping them into brush eliminated the rolling.

The Helijump Procedure

1. The reaction of the dummy while landing in the open or in the vegetated areas was similar to the human body's natural reaction, without muscular compensation. During most jumps, particularly those from the moving helicopter, the dummy settled easily into the green limbs, or rolled easily to the open ground. The tests indicated that giving way to natural body reaction is safest.

2. Jumps in medium oak and heavy chamise occasionally caused branches to lodge in the armpit and the crotch area of the dummy. When the dummy's arms were folded across his lower chest, and his legs placed tightly together, the chance of limbs lodging in these regions seemed to be reduced.

3. During the jump into medium chamise, the dummy fell over the larger boughs when landing, causing the head to be snapped back. Tucking the chin and hunching the shoulders would help to prevent a similar happening under actual conditions. (The smokejumpers' program recommends chin tucking and shoulder hunching while making ground contact. (11)).

RECOMMENDATIONS

The Helijump Suit

Addition of felt padding to certain parts of the helijump protective suit was recommended to the Missoula Aerial Equipment Development Center. The additions are being included in all current suit models.

The Helijump--Picking the Jump Spot

1. Pick a spot out of the anticipated path of the fire.
2. The helicopter must be able to reduce speed to 10 miles per hour or less during the jump.
3. Maximum safe jump height is 10 feet.
4. Flag your tools before the drop so they may be easily located.
5. Pick a flat area if you can.
   a. Pick an open, bare area if possible, where you can see what is on the ground.
      (1) If it is grass, watch for hidden rocks or logs.
      (2) Avoid uneven ground, rocky areas or burns with sharp stubs.
   b. If you have to jump into vegetation--
      (1) Vegetation should be not taller than 8 feet (Helicopter skids will be 2 feet above the tallest stem).
      (2) Avoid all densities of manzanita.
      (3) Avoid any vegetation with a lot of visible dead material. Pick a green patch in which to jump.
      (4) Vegetation best suited for jumping includes--

         Scrub oak
         Chamise
         Buckbrush, or Buckthorn
         Coniferous reproduction

         Light to medium buckbrush and scrub oak make the best jump cushions.

         (a) Jump near the edge of light and medium buckbrush and scrub oak, otherwise you could become entangled.
         (b) Jump near the edge of deliquescent species. If you jump into the center of such species, a foot may lodge in the crotch. Branches are most supple at their ends.

        (c) Remember that all dense vegetation could hide rocks or logs.

c. If you have to jump on a slope--

    (1) Pick a slope under 60 percent

    (2) Pick a slope where the helicopter can contour across the slope. The jumper must be on the uphill side.

    (3) Pick an open slope, if possible, where you can see what is on the ground.

    (4) Avoid broken hillsides and bluffs. If you have to jump on a slope with vegetation--

        (a) Jump into safe cover type only.

        (b) Be sure of your footing when you land. Watch for uneven ground, rocks, or other obstructions.

        (c) On moderate slopes--15-30 percent jump between clumps of vegetation if possible. They will stop you from rolling.

    (5) Drop your flagged tools into a brush clump, if possible, where they won't roll.

The Four-Pass Helijump Technique

IMPORTANT: Do not attempt a helijump unless:

a. You are trained and experienced in the technique.

b. The pilot is trained and experienced in the technique.

c. You are wearing the helijump protective suit with headgear and face mask, heavy gauntlet gloves, and high-top, sturdy boots.

1. High Level Reconnaissance Pass

The pilot and jumper will pick, in general, the safest jump area. Do not jump ahead of the fire. (See guidelines for picking the jump spot.)

2. Low Level Reconnaissance Pass

The pilot and jumper will pick the specific jump spot. Watch the fire. Know guidelines for picking a jump spot. Pilot may test flying stability.

3. Tool Drop Pass

Drop tools away from actual jump spot. Pilot may test ground effect and rotor clearance on this pass.

4. Jump Pass

During the approach to the jump spot:

a. At pilot's signal, jumper unfastens safety belt. Be sure belt is completely free.

b. At pilot's signal:

   (1) Grip both sides of the open door firmly.

   (2) Swing the right leg out to the skid. Plant foot securely against the skid near the gear leg.

   (3) Swing left leg to skid and plant foot securely.

   (4) Brace right leg snugly against skid gear leg. Brace right buttocks against body of the helicopter. Keep shoulders well back toward the body of the ship. The closer your weight is to the center of the gravity of the helicopter, the easier and safer the jump becomes.

   (5) When in position and ready for the jump, wait for pilot's signal.

   (6) At pilot's signal:

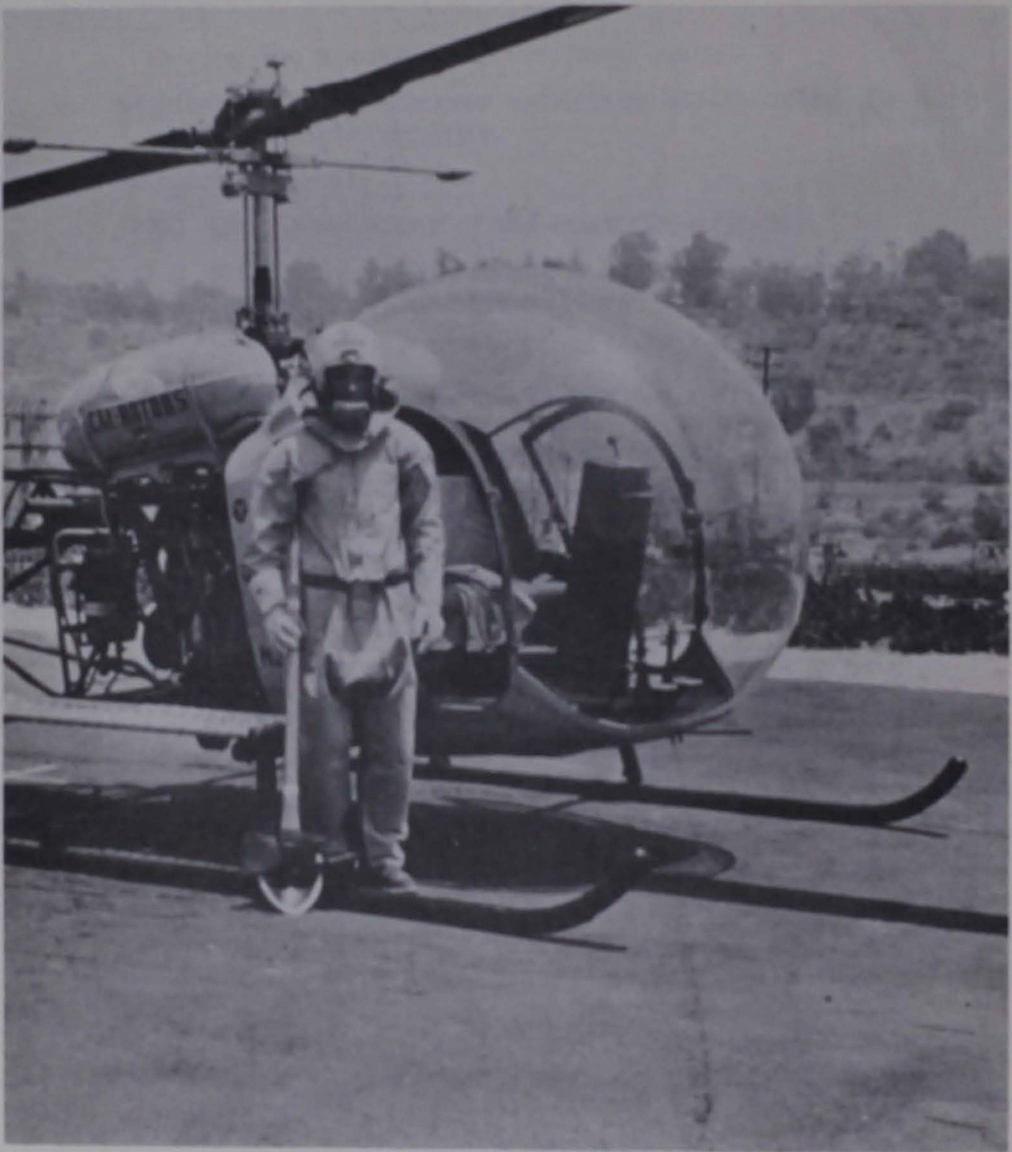
      (a) Step off immediately without exerting undue backward pressure against the helicopter skid. Do not push off.

      (b) After leaving skid, keep your legs together.

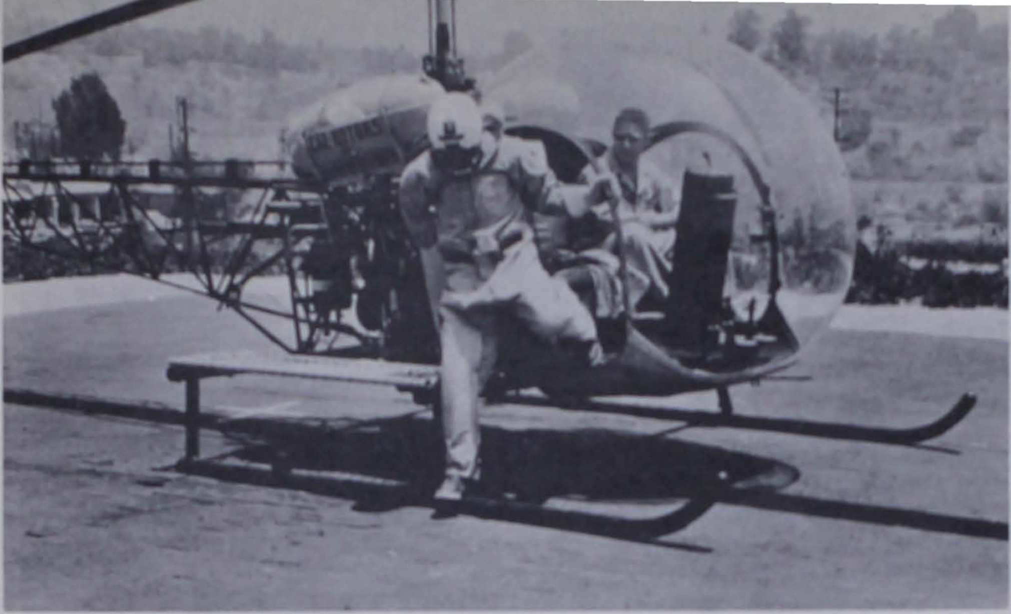
      (c) Fold arms across lower chest, elbows snug against body. Tuck chin down to chest.

SUMMARY

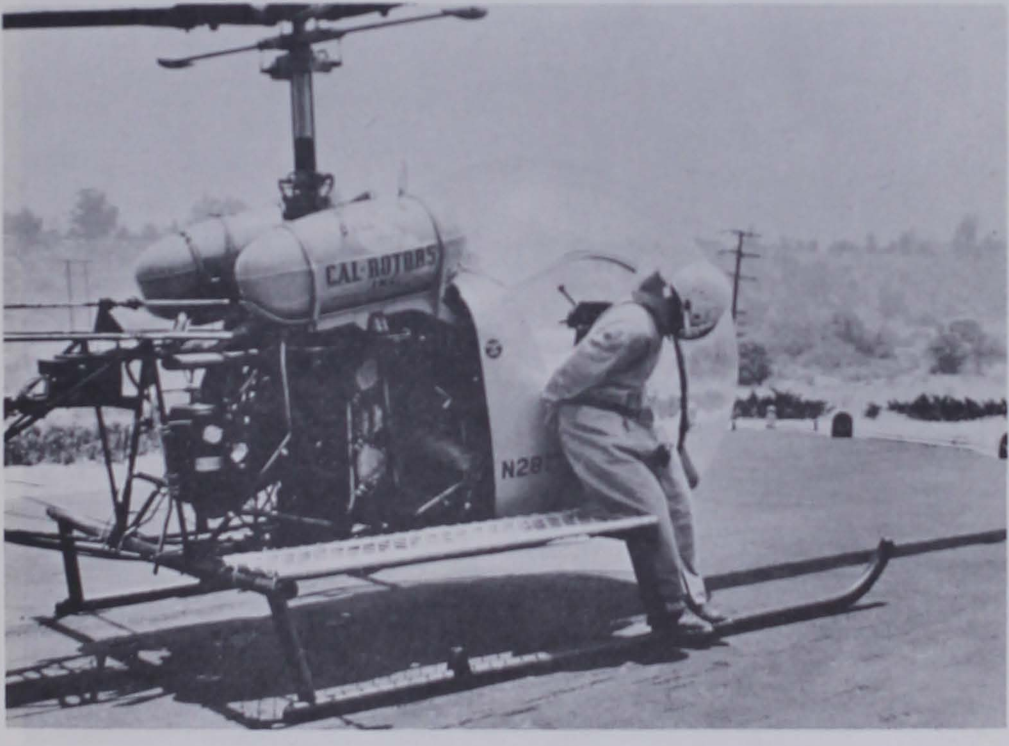
THE HELIJUMP TECHNIQUE PICTURED



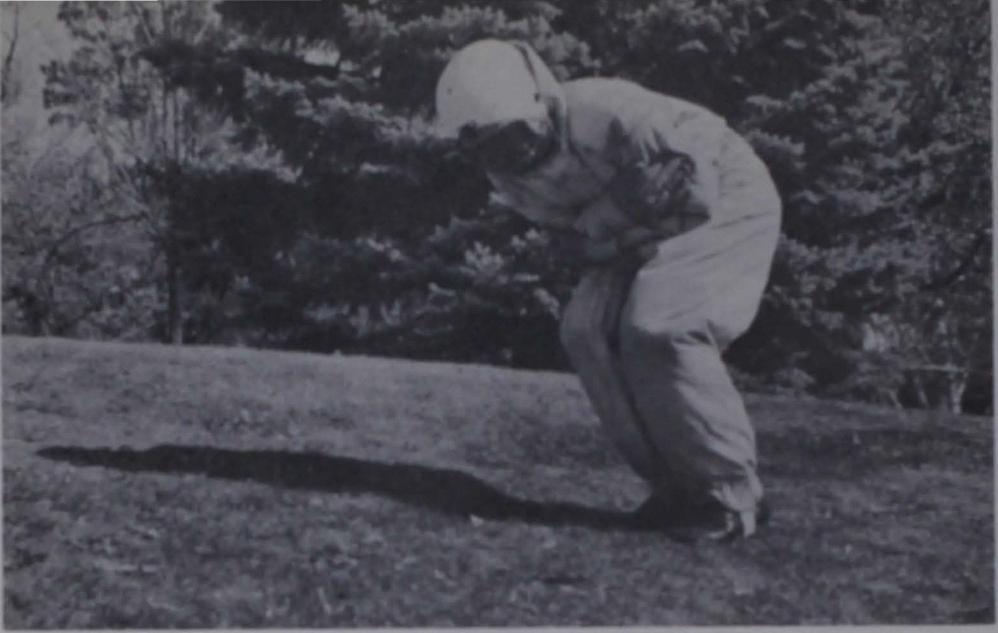
1. Before you jump--
    - Be sure you are trained in the technique.
    - Be sure the pilot is trained in the technique.
    - Wear the helijump protective suit--with headgear, heavy gloves, and high sturdy boots.



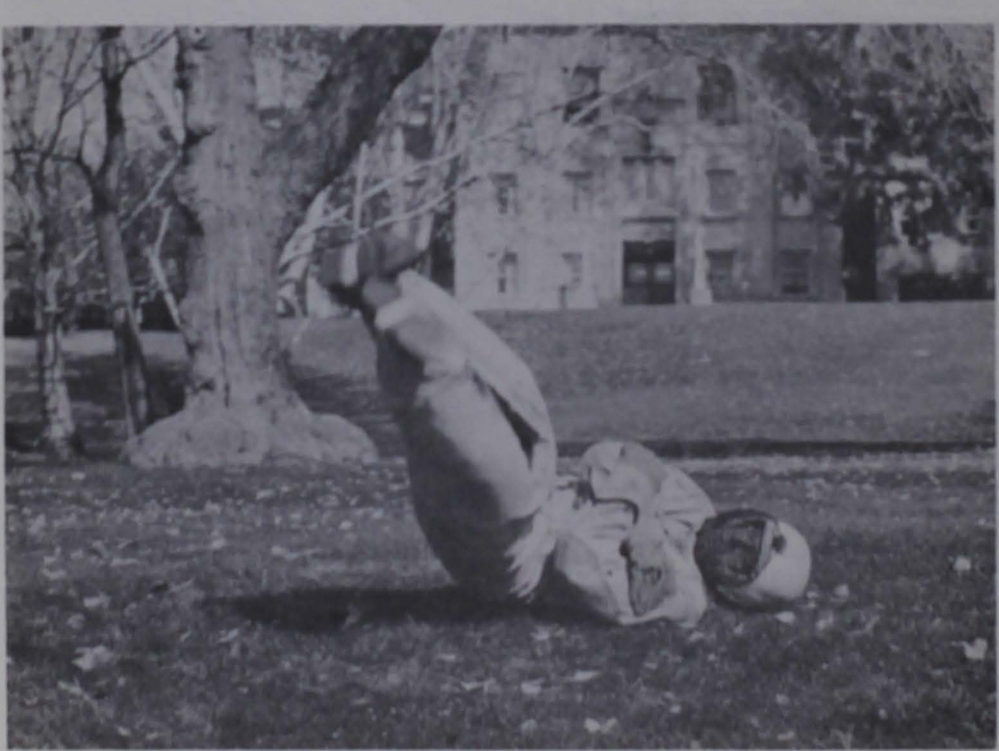
2. At pilot's signal, grip both sides of the open door firmly, swing the right leg to the skid. Plant foot firmly against the skid gear leg. Swing left foot beside it.



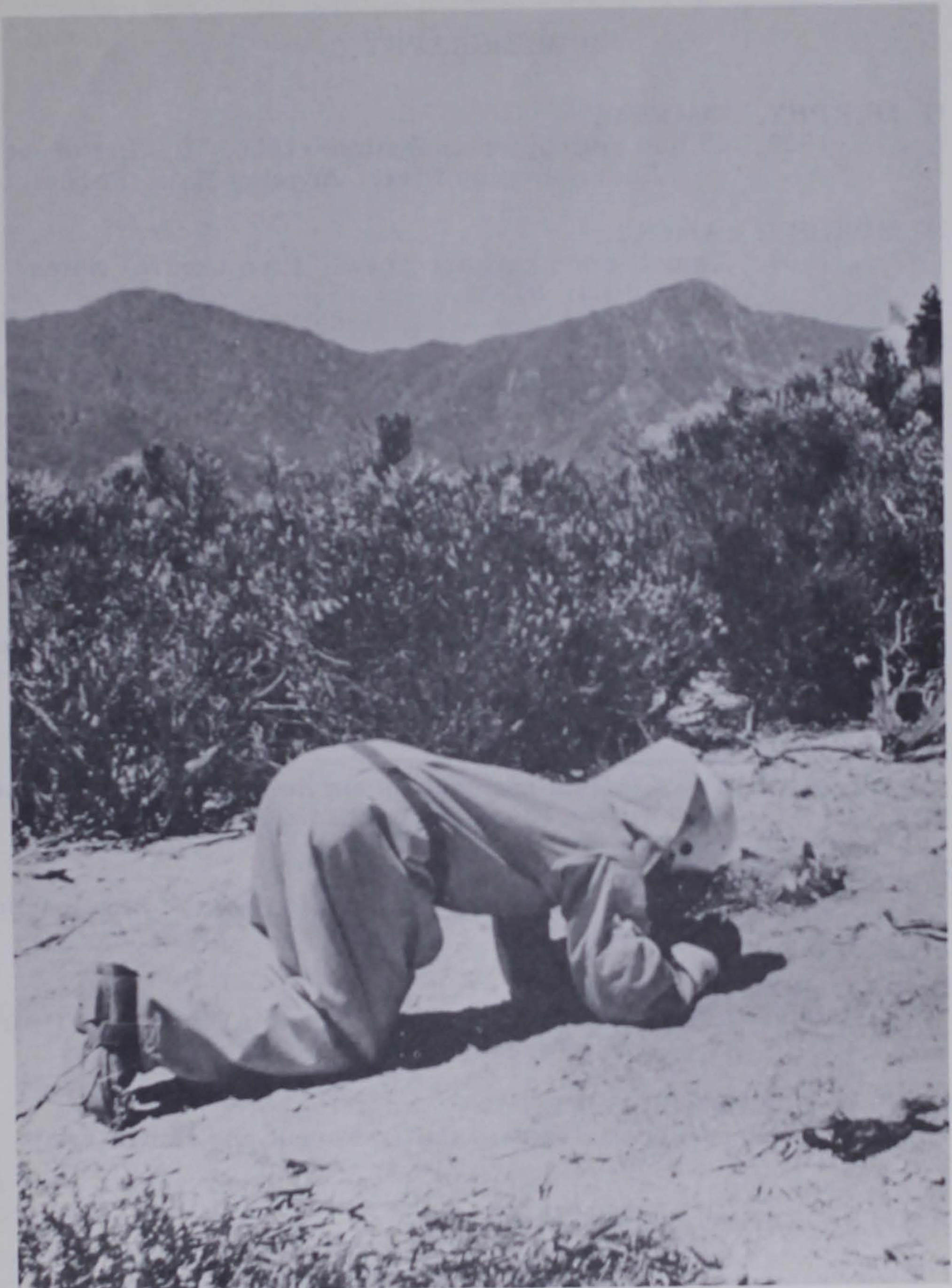
3. Keep lower legs snug against skid gear leg. Lean buttocks against body of ship. The closer your weight is to the center of gravity of the helicopter, the easier and safer the jump becomes. Wait for pilot's signal to jump.



4. At pilot's signal, fold your arms across the lower chest, elbows snug at side, chin tucked. Keep your legs together. When you hit the ground, relax and roll.



5. Roll with the direction of flight of the ship. Keep your elbows snug at your side, your legs together, and your chin tucked.



6. Remain on the ground until the helicopter is safely away. Wave streamer to indicate to the pilot "all O. K.".

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MISCELLANEOUS PAPER No. 33
REVISED MAY 1960

DIRECTIONS for using LINDANE SPRAYS to control IPS BEETLES in CALIFORNIA

by ROBERT L. LYON

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SUMMARY

WHAT TO USE AND HOW		For details see page
SPRAY MATERIALS	...a solution of lindane in diesel oil	1
MIXING THE SPRAY	...mix thoroughly; 0.2 percent solution by weight	2
INSECTICIDE SPRAYER	...use portable, general utility sprayer; 3- to 5-gallon capacity	4
SPRAY NOZZLE	...use nozzle that produces a coarse cone-shaped spray rather than a mist.	5
PREPARATION OF INFESTED MATERIAL	...trees need to be felled (that's all); slash needs no special preparation	5
SPRAY APPLICATION	...hold nozzle 1 to 1½ feet from bark; apply spray to point of wetness, not runoff	5
TIMING OF SPRAY	...apply spray not more than 1 week before adult beetles begin to emerge	6
SAFETY PRECAUTIONS	...lindane is toxic if swallowed or absorbed; read and heed the label...	6
OTHER POINTS TO REMEMBER		
EVALUATION OF CONTROL	...ask for help from an experienced appraiser	7
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LINDANE AS A PROTECTIVE SPRAY	...may prevent attacks on slash, sawlogs, and standing green trees	8

DIRECTIONS FOR USING LINDANE SPRAYS TO CONTROL IPS BEETLES IN CALIFORNIA

By Robert L. Lyon
Division of Forest Insect Research

Directions for controlling ips beetles with lindane were issued by the Experiment Station soon after this material showed promise as a residual spray. [1] Experience since then has shown a need for changes; these are contained in this paper.

SPRAY MATERIALS

The spray to use is a solution of lindane in diesel oil. Lindane is sold either in pure form (99 percent or better) or as an ingredient in the compound benzene hexachloride (BHC). BHC is a mixture of chemicals, one of which is lindane.

The lindane content of BHC is variable: generally between 10 and 30 percent by weight. The amount of lindane in the BHC you buy must be known exactly because the lindane fraction is the only part toxic to insects and is the only part that needs to be considered when mixing a spray. The amount of lindane in any sample of BHC is clearly marked on the label and is always referred to as "gamma isomer" not "lindane."

The materials needed to formulate the spray are diesel oil and the insecticide either as lindane or as BHC. Kerosene may be used in place of diesel oil but is more expensive.

Lindane or BHC may be purchased in several different forms:

1. Solution concentrate--the insecticide dissolved in an oil solvent with nothing else added.

2. Technical product--the dry, powdered insecticide with nothing added.

3. Emulsion concentrate--the insecticide dissolved in an oil solvent along with an emulsifier which makes the concentrate mix readily with water.

4. Wettable powder--the insecticide mixed with an inert powder and a wetting agent which permits the wettable powder to be dispersed or suspended in water.

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[1] Lyon, Robert L. Directions for using lindane sprays to control pine engravers. Pacific Southwest Forest and Range Expt. Sta. Misc. Paper No. 33, 5 pp., April 1959.

5. Dust--the insecticide mixed with or absorbed on an inert powder.

The solution concentrate (preparation 1) is the most suitable form. It is recommended above all other preparations.

The technical product (preparation 2) can be used but is less convenient because it does not mix well with diesel oil. Lindane is about three times more expensive when sold as "lindane" than when sold as "gamma isomer" of BHC, so it is cheaper to get BHC where you intend to purchase the ingredients separately and mix them yourself.

The emulsion concentrate (preparation 3) is not recommended but can be used if it is a brand that will dissolve in diesel oil. The emulsion concentrate is made to be mixed with water, not oil. So it often disperses in oil only in the form of discrete droplets. The stability of these "homogenates" varies. Some settle out rapidly on standing, especially at low temperatures. And they may undergo physical and chemical changes that make it impossible to redisperse them.

Wettable powders or dusts (preparations 4 and 5) are not suitable. Both of these materials contain inert powders which will not dissolve in oil, but will leave a sludge that can plug up spray equipment and cause much inconvenience.

Some California sources of lindane and BHC are:

California Spray-Chemical Corp.--Fresno, Richmond, Sacramento, San Jose, and Whittier.

Niagara Chemical Division, Food Machinery and Chemical Corp.--Richmond.

Stauffer Chemical Co.--Berkeley, Los Angeles, and San Francisco.

MIXING THE SPRAY

The finished spray must be a 0.2 percent solution of lindane (as lindane or as gamma isomer of BHC). This means that each 100 pounds of mixed spray contains 0.2 pound of lindane (or 1 part of lindane in 500 parts diesel oil by weight).

The amount of material to use in making a spray mixture of the proper concentration depends upon the form in which the lindane is obtained.

If you use the dry technical insecticide, the correct amounts to add to one gallon of diesel oil for a 0.2 percent lindane spray are--

Compound	Percent gamma isomer	Weight in grams (28 grams = 1 ounce)
Lindane	100	6
BHC	30	21
BHC	25	25
BHC	20	31
BHC	17	36
BHC	15	41
BHC	12	51
BHC	10	62

When oil solution concentrates are used, it is easier to measure the amounts of concentrate and diesel oil in parts by volume. When the weight of insecticide in the concentrate is known, the following formula can be used to find the correct proportions for a finished spray:

$$\left[\frac{\left(\frac{A}{B}\right) - A}{6.8}\right] - 1 = \text{parts of diesel oil to one part of concentrate by volume.}$$

A = pounds of lindane (or gamma isomer) in one gallon of concentrate.

B = percent solution wanted (expressed as a proportion of 1).

Here is a frequently used example, where A = 1.7 pounds and B = 0.2 percent (0.002 when expressed as a proportion of 1).

$$\left[\frac{\left(\frac{1.7}{0.002}\right) - 1.7}{6.8}\right] - 1 = 124 \text{ parts (quarts, gallons, etc.)}$$

The correctness of your answer can be checked by the following calculation:

$$\frac{A}{6.8 \times \text{answer}} = \frac{1.7}{6.8 \times 124} = \frac{1.7}{843.2} = 0.002 \text{ or } 0.2 \text{ percent}$$

When the amount of insecticide in the concentrate is shown only as a percent of total weight, the ratio of ingredients to make a finished lindane spray can be determined by the following formula (but the formula using actual weight is more accurate):

$$\frac{A}{B} \times 1.2 = \text{parts of diesel oil to one part of concentrate by volume.}$$

A = percent of lindane (or gamma isomer) in concentrate.

B = percent solution wanted.

An example where A = 20 percent and B = 0.2 percent is:

$$\frac{0.20}{0.002} \times 1.2 = 120 \text{ parts (quarts, gallons, etc.)}$$

It is most convenient to use the solution concentrate. You can mix this with diesel oil when and in the amount needed, or you can contract to have the mixed spray supplied by a private formulator.

The need for thorough blending of concentrate and diesel oil cannot be overemphasized. Improper mixing will seriously impair the effectiveness of the spray. Some concentrates mix well, others do not. It is important to learn beforehand how well the brand of concentrate mixes with diesel oil before you decide on a purchase. It is also important to know that once mixed, the concentrate will stay mixed and will not settle out on standing.

Temperature will affect mixing properties. Low temperatures, sometimes encountered in the field, may strongly influence the ease with which blending can be done and the tendency of the insecticide to settle out or precipitate. Mixing can be done in the sprayer if the ingredients are freely miscible and do not settle out on standing.

INSECTICIDE SPRAYER

Use a portable, general utility or garden sprayer of about a 3- to 5-gallon capacity. Some suppliers are: Dobbins, Hudson, Indian, and Lofstrand. Be sure the sprayer can be used with oil solutions. Two types of sprayers are suitable for the job: (1) the compressed-air or compression sprayer and (2) the knapsack sprayer. The type you use depends on individual taste.

The compression sprayer is cylindrical and can be slung over one shoulder. It must be set down for repumping each time the air pressure in the tank is exhausted. The compression sprayer performs best if the tank is filled with spray to only 2/3 or 3/4 of capacity so that spraying time can be extended under a given head of air pressure. Some models can be equipped with refillable carbon dioxide cylinders. One fill can expel from 3 to 5 tankfuls of spray.

The knapsack sprayer is designed to be carried on the back, with adjustable straps to fit the individual operator. It is pumped continuously as you spray; there is no reservoir of compressed air as with the compression sprayer. The pump handle is brought forward so that it can be actuated while the sprayer is slung on the back. Some models permit the pump handle to be placed on either side of the tank for right- or left-handed operation. The sprayer is also equipped with an agitator which continuously mixes the spray as you pump.

It is important to use a good sprayer and get high-quality leak-proof performance. A poor sprayer is a hazard to the operator and cannot be depended upon to give the consistently good performance needed for proper application of residual sprays.

SPRAY NOZZLE

Use a nozzle that produces a cone-shaped spray. To avoid drift, the nozzle should produce a coarse spray, not a mist. A nozzle orifice 1/32 inch in diameter is a good working size.

Many sprayers are fitted with nozzles that can be adjusted for fineness of spray and spray shape or pattern, or have a conventional nozzle with accessory nozzle disks for producing the different spray emission characteristics.

PREPARATION OF INFESTED MATERIAL

Slash, whether scattered or in piles, may be sprayed without special preparation, except that interfering limbs from larger pieces may need to be cut to allow the applicator ready access for spraying.

Infested trees will normally need to be felled. Limbing is necessary only to the extent that limbs hamper the work. Limbs that hold the tree off the ground help get a good coverage of spray and should be left on.

SPRAY APPLICATION

Accurate, uniform application is most important to the success of the control effort. Take care to apply the spray uniformly to all the bark surface to the point of bark wetness only. Application to runoff is wasteful and unnecessary. Hold the nozzle between 1 and 1-1/2 feet from the bark while applying the spray.

The amount of spray that will be needed for trees of different size is shown below. These are average figures but they should provide an adequate guide to spray needs. The figures represent total spray requirements. Between 25 and 50 percent of the total is lost through drift and other causes.

Tree d.b.h.	Total bark surface area	Volume of spray		
(Inches)	(Square ft.)	(Gallons)	(Quarts)	(Pints)
4	20	-	-	1
6	39	-	1	0
8	62	-	1	1
10	90	-	2	½
12	126	-	3	½
18	235	1	2	0
24	345	2	0	1½
30	431	2	3	0
36	565	3	2	½

Spraying may proceed even though the bark is wet from rain, but not while it is raining or if the bark is so saturated that free water lies on the surface.

TIMING OF SPRAY AND RESIDUAL TOXICITY

For best results, the spray should be applied within a week before the adult beetles begin to emerge. Some reduction in potency will be sacrificed if the spray is applied much earlier than this.

The toxic life of lindane varies considerably depending especially on conditions in the field. Generally, the lindane deposit will begin to decline in toxicity probably in 1 to 3 weeks after being applied.

Lindane is not dissolved by water, so precipitation should not affect its toxicity except under conditions of heavy or prolonged rainfall, when water may erode the deposit away.

SAFETY PRECAUTIONS

The insecticide concentrate and the mixed spray are toxic to man when swallowed or absorbed through the skin. Both lindane and diesel oil can cause skin rashes to those sensitive to these compounds. Take these precautions:

1. Avoid contact with the spray. Stand to the windward while spraying.
2. Wash with soap and water when insecticide is spilled on the skin.
3. After spraying for several hours, bathe thoroughly, and launder clothes before using them again.
4. Destroy or bury empty insecticide containers.

The antidote for poisoning is given on the insecticide label. Instructions on the insecticide label should be carefully heeded.

EVALUATION OF CONTROL

The effectiveness of a chemical control effort is usually judged by the trend of the outbreak or the level of insect damage after spraying. An end to tree mortality is usually taken to mean that control was successful. On the other hand, continued tree mortality above economically tolerable levels is evidence that the control effort failed.

To single out the cause of failure is a difficult matter. Perhaps the spray used was not effective, detection of infested trees was not sufficiently complete, timing of the spray operation was not within acceptable limits, or formulation or application methods were inappropriate.

The effectiveness of the insecticide itself may be judged only by an experienced technician who can take appropriate samples of treated and untreated material to the laboratory for analysis. Even this is by no means conclusive, though such an analysis should indicate whether the insecticide spray was or was not the cause of control failure.

Furthermore, it is important to remember that an insecticide spray is only as good as the conduct of the whole control effort. No chemical control can be assured of working without skilled attention to all parts of the control program. The judgement of an experienced technician is needed in the application of chemical control, and each insect problem must be judged separately as to the need for and potential workability of a chemical control effort.

Field observations of beetle emergence from sprayed material have no meaning in the interpretation of the effectiveness of the insecticide. Holes chewed through the bark by emerging adults cannot be used to indicate how good a residual spray was. Lindane is a slow-acting insecticide which generally does not kill until 1 to 3 days after the beetles emerge, and the beetle contacts the insecticide only as it bores out and flies away.

LINDANE FOR OTHER BARK BEETLES

The effectiveness of lindane for controlling western bark beetles other than ips is not known. Preliminary research shows that lindane sprays may be effective on the western pine beetle (Dendroctonus brevicomis Lec.) and the mountain pine beetle (Dendroctonus monticolae Hopk.) if applied as a 1.5 instead of 0.2 percent solution. Field trials so far conducted on Dendroctonus beetles with a 1.5 percent solution also show that lindane holds considerable promise.

LINDANE AS A PROTECTIVE SPRAY

Lindane also promises to be useful in California in preventing bark-beetle attacks on slash, sawlogs, and standing trees. Though we have little experimental evidence to show that it works, we feel it merits a trial in the absence of other protective measures.

The spray formula to use can only be estimated because there is no experimental data to go by. A 0.2 to 0.5 percent solution should be effective. Again, the spray should be applied until the bark is just wet. With green standing trees, care should be taken to avoid getting spray on the foliage. The foliage can be burned by the spray and can be killed by heavy doses.

Before a protective spray is applied, examine the tree closely to make sure that beetles have not already attacked it. Trees cannot be protected once they have become infested. The foliage of a pine tree infested with bark beetles goes through various color phases--from a straw color to a reddish brown. When the foliage becomes straw colored, the tree is dead and cannot be saved by a protective spray. Even when green, the tree is beyond protection if infested with early stages of bark beetles.

Added protection of living trees can be had by applying repeat sprays every 4 to 6 months as long as bark-beetle-killed trees continue to show up near the trees to be protected. Slash and sawlogs cut in late spring or summer may need only one spraying to keep them from becoming infested because they will probably dry out and become unattractive to bark beetles before the protective effects of the spray are lost. This may not be true of slash or sawlogs cut in the fall since drying does not proceed as rapidly during the winter months; by spring of the next year, the protective effects of the lindane may have worn off, and beetles may still be attracted to the material.

> CAUTION: Lindane is a poison. Read carefully all directions on the container. The mixture of lindane and diesel oil recommended has the flammability of diesel oil alone and must be handled with the same precautions taken to avoid fires with diesel oil.

Mention of companies or products in this paper does not imply endorsement of these items nor disapproval of similar items not mentioned.

Miscellaneous Paper No. 34
April 1959

PACIFIC SOUTHWEST
FOREST AND RANGE
EXPERIMENT STATION
Berkeley - California

FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

Timber or Snags in 1959?

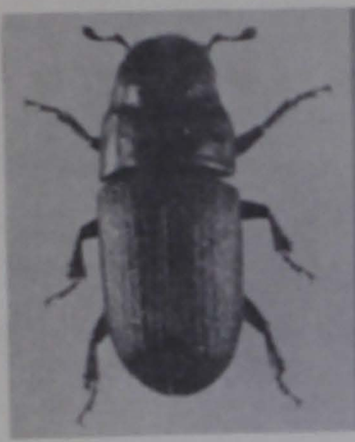
...quick action now may save trees from serious bark beetle damage this year

A bumper crop of bark beetles seems to be in the making in California's ponderosa pine forests this year. This is the conclusion Station entomologists have drawn from insect detection reports already turned in by field-going foresters, and from their own observations and knowledge of conditions leading up to outbreaks.

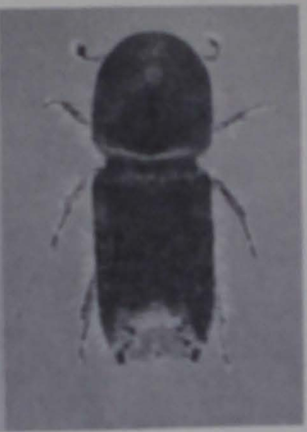
Past experience has shown that upsurges in bark beetle populations often occur during warm, dry seasons such as the one we are currently experiencing. These sometimes erupt into virulent epidemics, destroying thousands of board feet of valuable timber.

The prospect of serious damage is most critical in ponderosa pine stands at low elevations (below 4, 500 feet) in the Coast Range and Sierra Nevada. Unless foresters and timber operators are aware of the situation, they themselves may unknowingly contribute to the problem, and thereby lose a good percentage of their reserve timber, the trees on which they are depending for future cuts. However, if they are alert, they can do much to help keep damage to a minimum.

To see what often happens in years like this, why it happens, and just what specifically can be done toward keeping the beetles in check, let's take a look at the overall picture.



WESTERN PINE BEETLE



FIVE-SPINED ENGRAVER

Bark Beetles Join Forces

In the low-elevation ponderosa pine zone, the California five-spined engraver (Ips confusus (Lec.)) and the western pine beetle (Dendroctonus brevicomis Lec.) frequently team up to attack and kill standing green trees. This combination is most destructive in the wake of spring logging operations, road and powerline right-of-way clearings, and wind or snow breakage. It is especially potent in warm, dry years when the ability of trees to withstand insect attacks is liable to be reduced.

How Outbreaks Develop

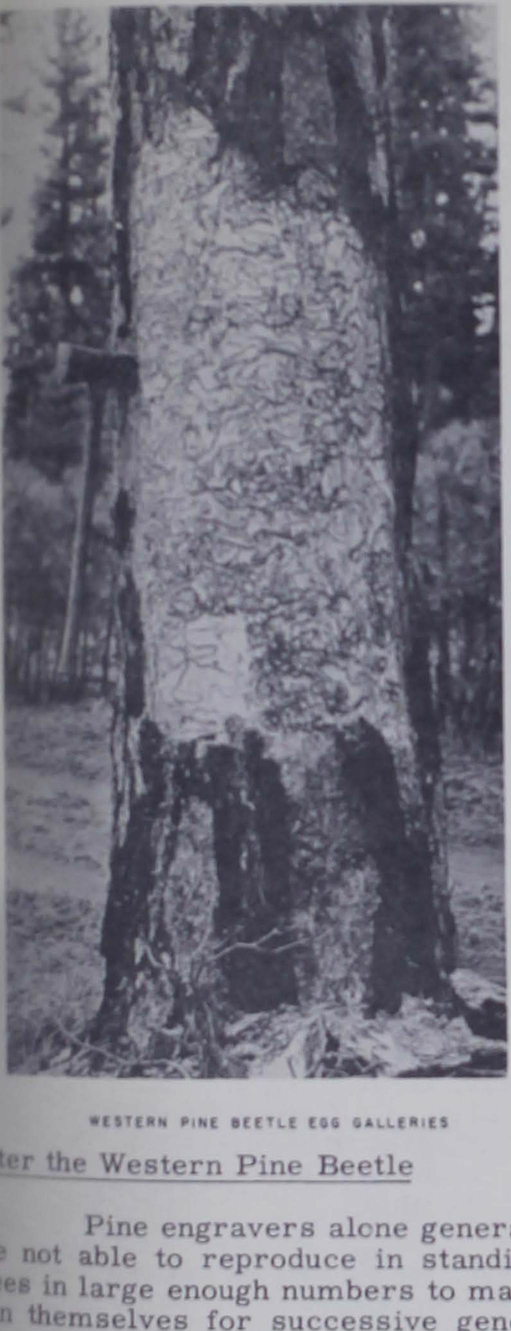
Outbreaks get started in fresh slash during the late winter and early spring months of years when breeding conditions for the beetles are favorable. Here's how they develop: In March or April, pine engravers attack and lay their eggs in cut or storm-broken ponderosa pine. In the spring months the engravers are generally unable to breed successfully in standing green trees at this time, but continue to produce successive generations in slash.

Under optimum conditions, it takes the beetles in slash less than 6 weeks to go through their normal course of development, from eggs to larvae, to pupae, finally to emerge as new adults.

SLASH

In dry years, even healthy trees seem to lose some of their ability to resist engraver attacks during the spring months. And by mid-June, when the late spring broods emerge, the beetles move to the green stand. Small trees, easily identified in late July or early August by their fading foliage, often are killed outright. Larger trees are usually only top-killed, creating "red tops" throughout the stand.

"RED TOPS"



WESTERN PINE BEETLE EGG GALLERIES

Enter the Western Pine Beetle

Pine engravers alone generally are not able to reproduce in standing trees in large enough numbers to maintain themselves for successive generations. But they play a key role in paving the way for the development of western pine beetle epidemics. Top-killed trees are prime fodder for the western pine beetle, which now enters upon the scene attacking the boles below the pine engraver. From this source spring huge western pine beetle populations that spread into the surrounding timber. There they and their progeny cause extensive tree-killing.

Why 1959 Promises to be a Bad Year

There are two primary reasons why this year looks like a bad one for ponderosa pine. The first is the presence of a large overwintering population of pine engravers, evidently the result of a buildup that occurred during the extended warm, dry weather late last fall. The second is the fact that the past winter and early spring months have been exceptionally warm and dry, creating conditions favorable to the beetles, but unfavorable to the trees. All that is needed to trigger an outbreak is an abundant supply of suitable breeding material. In some pole stands in the southern Sierra, breakage from winter storms already fulfills this requirement.

What Can Be Done to Hold Losses Down

Obviously, the time to nip insect outbreaks is before they get started. The majority of pine engraver-western pine beetle outbreaks stem from early season logging. By modifying certain practices, positive steps to forestall outbreaks can be taken.

The best preventative is to schedule cutting operations from mid-July to late fall or winter. If no fresh slash is available before mid-summer, explosive bark beetle buildups of the type that develop in spring slash will not occur.

When it is not practical to delay logging, as often is the case, lopping and scattering the limbs of felled pine tops left in the woods is the next best choice. Fresh slash above 3 inches in diameter is a potential source of trouble. By lopping and scattering the slash so as to expose it to the drying effects of the sun's heat, its capacity to produce beetles can be reduced by about 75 percent. Do not bunch or pile green slash from cuttings made between February and July, unless it is to be treated so as to prevent it from producing beetles.

Close utilization also helps to minimize the hazard from beetles. Utilizing to an 8-inch top instead of, for example, a 14-inch top will eliminate 80 percent of the insect breeding material that otherwise would be left in the woods. Together, lopping and scattering plus close utilization can reduce the beetle production potential of ponderosa pine slash by 95 percent.

Sometimes, for one reason or another, it is impractical to adopt any of these practices. When this happens, and pine engravers begin to build up in slash, one ace in the hole is left--direct control. Recent research by Station entomologists has shown that lindane spray lightly applied to infested material is deadly to pine engravers. Instructions for preparing and using this insecticide can be obtained from the Station.

IN SHORT

Increased damage from bark beetles is in prospect in the ponderosa pine belt this year. Most likely places for outbreaks to start are around spring cuttings, particularly logging operations, and land clearings for roads, powerlines, and other purposes; around pruning or thinning operations in green timber, and in stands damaged by winter storms. To keep damage to a minimum, here are the things that can be done.

1. Schedule cuttings after mid-July when possible.
2. Lop and scatter fresh slash from spring cuttings. Do not bunch or pile green slash.
3. Utilize all cut trees to an 8-inch top diameter when practicable; avoid cutting small trees where there is a choice.
4. Check slash and surrounding timber periodically for signs of aggressive bark beetle infestations.
5. Use direct control measures when necessary to control outbreaks.

More detailed information about the California five-spined engraver and the western pine beetle is contained in the publications listed below. For copies write to Director, Pacific Southwest Forest and Range Experiment Station, P. O. Box 245, Berkeley 1, California.

Keen, F. P.
1955. The western pine beetle. U. S. Dept. Agr. Forest Pest Leaflet 1, 4 pp., illus.

Lyon, R. L.
1959. Lindane--a better insecticid for pine engraver beetles. Cal Forest and Range Expt. Sta. Misc. Paper 29, 2 pp., illus.

Lyon, R. L.
1959. Directions for using lindane sprays to control pine engraver Pacific Southwest Forest and Range Expt. Sta. Misc. Paper 5 pp.

Stevens, R. E.
1959. Ethylene dibromide sprays for controlling bark beetles in California. Calif. Forest and Range Expt. Sta. Res. Note No. 147, 6 pp., illus.

Struble, G. R.
1955. California five-spined engraver beetle. U. S. Dept. Agr Forest Pest Leaflet 4, 4 pp., illus.

Struble, G. R. and Hall R. C.
1955. The California five-spined engraver, its biology and control, U. S. Dept. Agr. Cir. 964 21 pp., illus.

Whiteside, J. M.
1951. The western pine beetle, a serious enemy of ponderosa pine U. S. Dept. Agr. Cir. 864, 11 pp., illus.

(Compiled from material furnished by
the Division of Forest Insect Research)

AGRICULTURE—FOREST SERVICE—SAN FRANCISCO

MOUNTAIN EVAPORATION

DATA FROM THE SAN DIMAS EXPERIMENTAL FOREST

BY LYLE F. REIMANN

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MISCELLANEOUS
PAPER No. 35
JULY 1959

PACIFIC SOUTHWEST
FOREST AND RANGE
EXPERIMENT STATION
BERKELEY - - - CALIFORNIA

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

MOUNTAIN EVAPORATION

Data from the San Dimas Experimental Forest at Elevations of 1,500 to 5,100 Feet

By Lyle F. Reimann

Miscellaneous Paper No. 35

July 1959

PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE

ACKNOWLEDGMENT

The data presented here were made possible by Everett L. Hamilton, Meteorologist, (retired) who planned and supervised San Dimas Experimental Forest climatological studies for many years; and Lowell A. Andrews, Forestry Aid, and Frances B. Withers, Statistical Clerk, who provided the major assistance in the collection and compilation of the data.

Studies reported here were
conducted in cooperation with

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF FORESTRY

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THE AUTHOR: Lyle Reimann has been a member of the San Dimas Experimental Forest staff since 1938. For the past 10 years he supervised the compilation of all climatic, hydrologic and related records. Prior to his present assignment he was a member of the field staff on the experimental forest.

MOUNTAIN EVAPORATION

Data from the San Dimas Experimental Forest at Elevations of 1,500 to 5,100 Feet

Lyle F. Reimann

Great amounts of water are lost for human and other biological use by evaporation. This loss occurs from many types of surfaces, including soil, vegetation, and free water. Measurement of these losses, however, is relatively difficult except from a free water surface. Therefore, extensive measurement of this particular evaporation process is in progress throughout the world. Although free water surface evaporation measurements cannot be applied directly to determine quantitative losses from reservoirs, plants, or soils, they serve as useful regional indexes. Evaporation data representing monthly summaries of loss of water from a free water surface are presented in this publication. The measurements were made at four elevations, all in chaparral openings with southerly exposures on the San Dimas Experimental Forest, in the front range of the San Gabriel Mountains of southern California.

The San Dimas Experimental Forest was established in 1933 as a brushland watershed management research field laboratory. Research objectives are to determine how watersheds function, and to develop methods of watershed management that will insure the maximum yield of usable water with the minimum of sedimentation and flood hazard. Fundamental to these objectives, inventories of local climate were made at four climatic stations. These stations were located at several elevations on the experimental area (fig. 1), and were equipped with instruments to obtain measurements of evaporation and other climatic records (table 1).

The following evaporation data are mostly from U. S. Weather Bureau type evaporation pans 4 feet in diameter and set above ground level. In addition, data are given from San Dimas pans set 18 inches in the ground at two locations.

Table 1.--Equipment at climatic stations, San Dimas Experimental Forest

Item	San Dimas Canyon	Tanbark Flat	San Gabriel Divide	Fern Canyon
Louvered instrument shelter	x	x	x	x
Maximum and minimum thermometers	x	x	x	x
Hygrothermograph	x	x	x	x
Whirling type psychrometer	x		x	x
Aspirating psychrometer		x		
Taylor shallow black pan evaporimeter		x		
Weather bureau type evaporation pan	x	x	x	x
San Dimas evaporation pan	x	x		
Anemometer at 18-inch elevation, continuous recording	x	x		
Anemometer at 7-foot elevation, continuous recording	x	x	x	x
Anemometer at 30-foot elevation, continuous recording		x		
Wind direction transmitter	x	x	x	x
Soil temperature thermometers and thermograph	x	x	x	x
Recording and non-recording rain gages	x	x	x	x

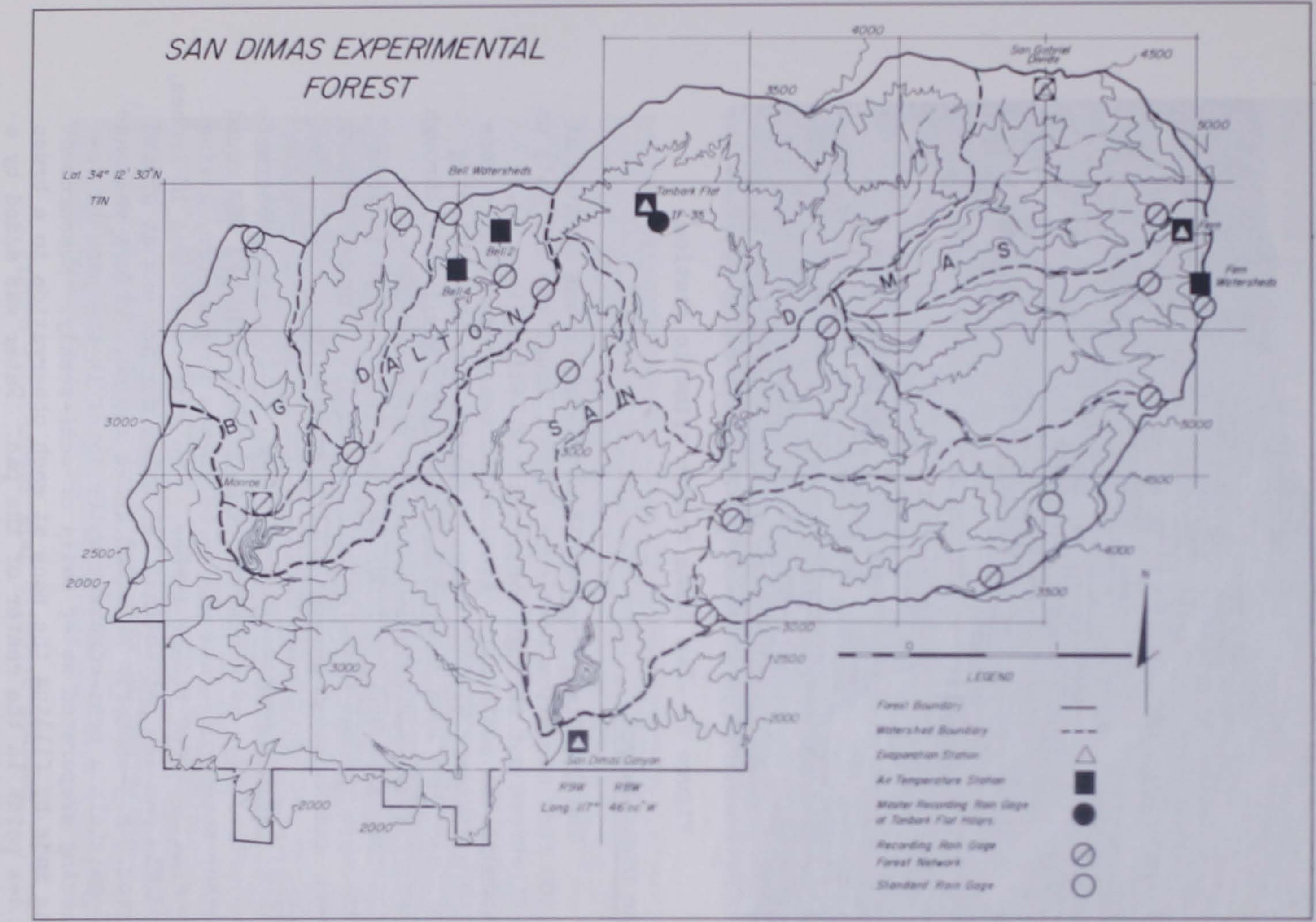
SAN DIMAS EXPERIMENTAL FOREST
Lat 34° 12' 30"N
T1N
Bell Watersheds
Bell 2
Bell 4
Tanbark Flat
TF-35
San Gabriel Divide
Fern
Fern Watersheds
BIG DALTON
SAN DIMAS
Monroe
San Dimas Canyon
R9W
R8W
Long 117° 46' 00"W
4000
4500
3500
5000
3000
2500
2000
LEGEND
Forest Boundary
Watershed Boundary
Evaporation Station
Air Temperature Station
Master Recording Rain Gage at Tanbark Flat Hdqrs.
Recording Rain Gage Forest Network
Standard Rain Gage
0
1

Figure 1.--San Dimas Experimental Forest in the San Gabriel mountains of southern California showing climatic stations and present rain gage locations.

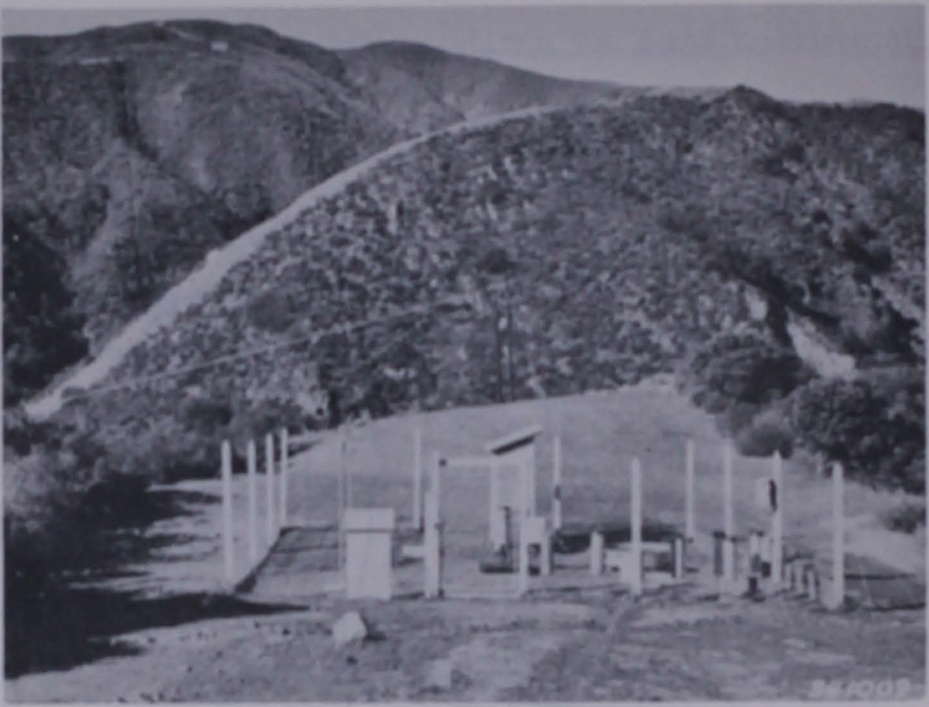

Figure 2.--San Dimas Canyon climatic station.

San Dimas Canyon

The San Dimas Canyon climatic station was located at 1,500 feet elevation (latitude 34°09', longitude 117°46') on a firebreak cut through chaparral vegetation (fig. 2). Exposure was southwest. Evaporation measurements were made with a standard Weather Bureau type pan for the following periods: May 1936 through November 1936, April 1937 through January 1938, and July 1938 through September 1943. In addition, a sunken San Dimas pan was used for the periods June 1936 through November 1936, April 1937 through January 1938, and May 1938 through September 1940.

The San Dimas pan was designed locally to approximate characteristics of Rohwer's Colorado pan. Our pan was round rather than square and was 35.68 inches in diameter, giving an area of 1,000 square inches. The water depth was 18 inches, and the pan was set so that the water surface was at ground level. A 3-inch rim extended above ground. Effort was made to maintain a near-constant water level in the pans by replacing evaporated water daily or semi-weekly. Measurement was made by filling the pans at each observation to a brass index point in the center of the pan. Water was added by a graduate calibrated on the basis of pan area and water depth.

Tanbark Flat

The Tanbark Flat climatic station was first located just above the field headquarters of the San Dimas Experimental Forest at 2,725 feet elevation (latitude 34°12', longitude 117°46') in an opening in chaparral vegetation with a south exposure. Evaporation measurements were made with a standard Weather Bureau type pan from June 27, 1935 through October 10, 1938 and by a San Dimas type pan from June 27, 1935 through September 8, 1938. May 13, 1937 a new station was installed, 1,100 feet north by west of the first station, at 2,800 feet elevation with a southern exposure in an area surrounded by shrub vegetation (fig. 3). On July 12, 1938 Weather Bureau type and San Dimas type evaporation pans were installed at the new station. The Weather Bureau pan is still in operation, but the San Dimas pan was discontinued January 31, 1941. In addition, a Taylor shallow black pan evaporimeter was installed May 11, 1937 and operated until October 20, 1954. This was a flat black pan 1 inch deep mounted on a Fergusson weighing rain gage mechanism. The pan was 25.298 inches in diameter, providing an evaporation surface 10 times the area of a standard 8 inch rain gage. Therefore, the weighing mechanism operating in reverse could record minute water losses, the smallest chart division representing 0.005 inch depth.

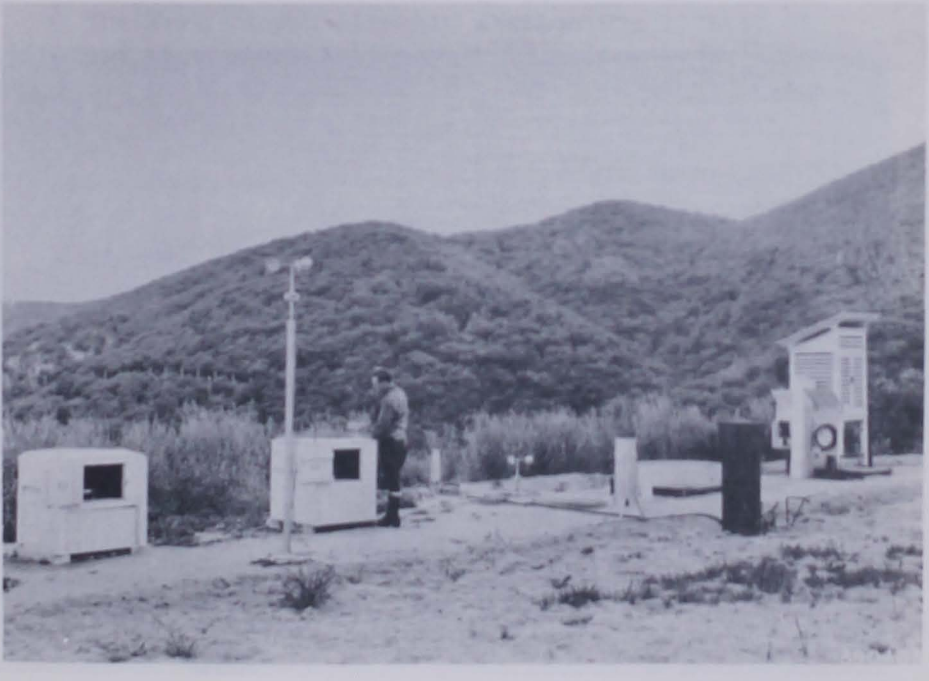

Figure 3.--Tanbark Flat climatic station.

Evaporation data for the Weather Bureau type pan and the San Dimas type pan for the period July 1935 through June 1938 were interpolated for the new station from data obtained at the first Tanbark Flat climatic station on the basis of a comparison of data taken simultaneously at both stations.

San Gabriel Divide

The San Gabriel Divide climatic station was located at 4,350 feet elevation (latitude 34°13', longitude 117°43') in an opening in the chaparral on a point near the crest of a ridge (fig. 4). Exposure was due south. A standard Weather Bureau type evaporation pan was used for the period June 1936 through September 1936, August 1937 through November 1937, and May 1938 through September 1943. Records were interrupted at times during winter seasons by freezing temperatures and snow conditions.

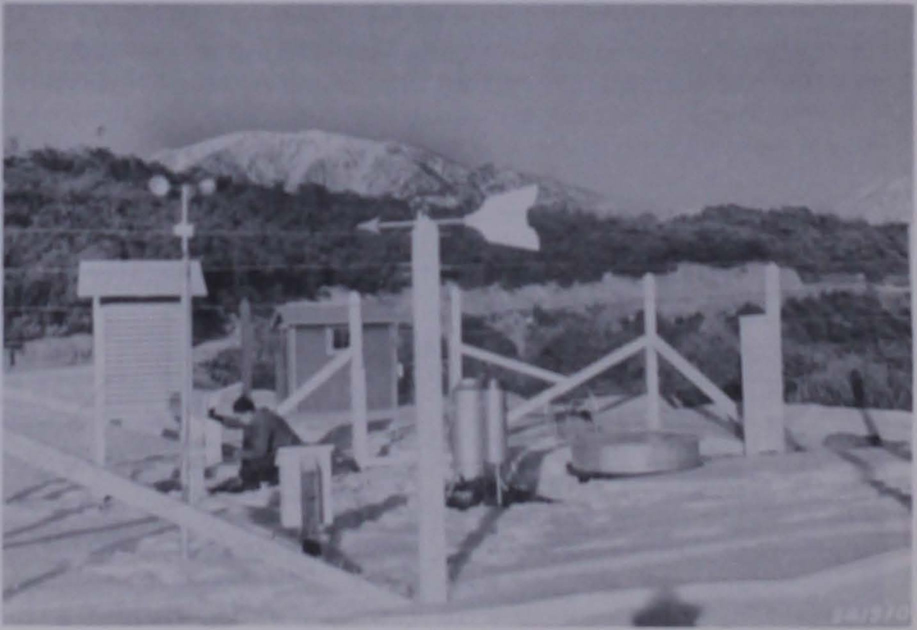

Figure 4.--San Gabriel Divide climatic station.

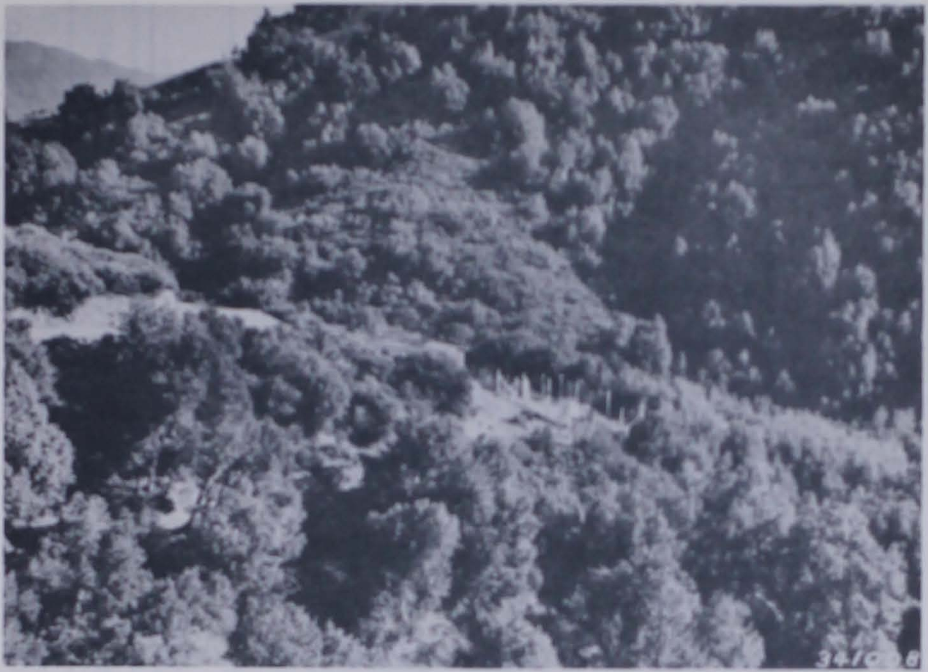

Figure 5.--Fern Canyon climatic station.

Fern Canyon

The Fern Canyon climatic station was located at 5,100 feet elevation (latitude 34°12', longitude 117°42') in a small opening surrounded by chaparral vegetation (fig. 5). Exposure was south. The station and surrounding brush cover were destroyed by fire in November 1938. The area was fairly well revegetated by sprouting shrubs within the next 3 years. Evaporation measurements were made with a standard Weather Bureau type pan for the periods May 1937 through October 1937, April 1938 through July 1938, December 1938 through September 1940, and January 1942 through September 1943. Evaporation records during the winter season were interrupted frequently by freezing temperatures and snow conditions.

SAN DIMAS EXPERIMENTAL FOREST

San Dimas Canyon Climatic Station, Elevation, 1,500 feet

Evaporation Data

WEATHER BUREAU PAN

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
							Surface inches						
1935-36	--	--	--	--	--	--	--	6.87	8.73	9.69	8.68	7.65	--
1936-37	5.77	3.51	--	--	--	--	2.50	4.81	6.82	9.07	9.84	7.88	--
1937-38	5.96	3.13	2.20	3.69	--	--	--	--	--	8.08	8.62	7.21	--
1938-39	4.30	4.20	2.71	2.03	2.21	2.04	4.24	5.43	7.68	9.03	8.51	5.41	57.79
1939-40	4.28	3.71	3.06	1.00	1.53	3.83	3.22	6.46	6.92	9.48	8.73	6.71	58.93
1940-41	5.62	3.25	1.82	1.62	1.00	2.00	2.08	6.63	5.96	8.81	6.90	5.75	51.44
1941-42	3.93	3.66	1.74	2.27	2.63	3.86	2.98	5.95	6.83	9.82	8.60	6.27	58.54
1942-43	4.55	2.69	2.47	2.79	2.27	2.40	3.36	6.29	6.89	8.17	7.97	7.31	57.16
5-year mean[1/]	4.54	3.50	2.36	1.94	1.93	2.83	3.18	6.15	6.86	9.06	8.14	6.29	56.78

SAN DIMAS PAN

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1935-36	--	--	--	--	--	--	--	--	7.58	8.31	7.92	5.27	--
1936-37	4.62	2.79	--	--	--	--	2.17	4.32	5.46	8.53	7.31	7.24	--
1937-38	4.91	2.85	1.91	2.59	--	--	--	4.00	6.14	8.22	7.85	7.06	--
1938-39	4.64	3.76	2.33	1.83	1.98	1.88	3.44	5.19	7.50	8.31	7.94	5.19	53.99
1939-40	3.84	3.04	2.53	.90	1.36	3.12	2.87	5.61	5.88	8.30	7.43	5.97	50.85

[1/] 5-year mean for the years 1938 to 1943.

SAN DIMAS EXPERIMENTAL FOREST
Tanbark Flat Climatic Station, Elevation 2,800 feet

Evaporation Data--Weather Bureau Pan

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
	Surface inches												
1934-35[1]	--	--	--	--	--	--	--	--	--	10.29	9.61	8.06	--
1935-36[1]	5.41	3.48	2.58	1.94	2.08	3.85	3.85	6.25	9.67	10.34	10.07	8.12	67.64
1936-37[1]	5.78	3.66	2.68	2.27	2.06	3.92	3.92	6.02	8.12	10.77	10.47	8.22	67.89
1937-38[1]	6.17	2.61	1.98	2.24	1.13	3.12	4.53	6.64	7.56	10.22	10.20	9.45	65.85
1938-39	5.62	6.00	3.26	2.78	2.89	3.96	5.26	5.53	7.89	9.56	11.58	8.32	72.65
1939-40	6.44	4.53	3.66	2.45	2.63	4.49	4.88	7.24	8.79	11.85	12.07	8.65	77.68
1940-41	6.96	4.00	2.00	1.50	1.71	2.77	3.35	6.61	6.82	10.19	8.06	7.42	61.39
1941-42	4.81	4.29	1.68	2.64	3.12	4.69	3.30	6.55	7.73	11.89	10.35	9.03	70.08
1942-43	6.10	4.12	3.42	3.32	3.15	3.22	4.41	6.77	7.14	9.91	9.38	9.14	70.08
1943-44	5.67	4.53	1.76	2.43	1.97	4.12	4.16	5.13	4.79	8.23	9.75	7.19	59.73
1944-45	5.66	2.37	2.43	2.32	2.26	2.95	4.90	5.56	5.55	9.75	8.50	7.58	59.83
1945-46	4.77	3.48	2.16	3.47	2.88	3.22	4.90	3.75	7.59	8.53	10.30	8.34	63.39
1946-47	5.08	2.50	2.24	3.03	2.75	3.06	4.53	5.49	6.36	11.36	8.86	8.28	63.54
1947-48	5.46	3.71	3.24	4.34	3.08	2.81	4.00	5.29	6.38	10.15	11.33	10.16	69.95
1948-49	5.76	5.04	2.75	2.11	1.94	3.05	4.65	4.84	7.02	9.10	9.51	8.90	64.67
1949-50	5.17	4.38	2.09	1.41	2.33	3.39	3.86	5.42	6.82	9.85	11.55	7.86	64.13
1950-51	7.58	4.40	3.18	1.85	2.53	4.43	3.23	6.22	7.02	10.90	10.98	10.10	72.42
1951-52	6.10	2.93	1.56	1.46	2.47	2.56	3.39	6.79	5.93	9.00	8.68	6.65	57.52
1952-53	5.87	2.19	1.43	2.41	3.16	3.51	3.45	5.53	6.54	10.29	9.32	7.76	61.46
1953-54	6.07	3.24	3.44	1.66	3.61	2.48	4.28	5.97	6.15	8.97	7.86	7.65	61.38
1954-55	5.96	3.43	1.94	1.35	2.40	3.88	4.50	4.43	6.13	8.64	9.49	9.25	61.40

Continued.

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
	- - -	- - -	- - -	- - -	- - -	Surface inches	- - -	- - -	- - -	- - -	- - -	- - -	- - -
1955-56	6.60	3.17	1.36	1.60	2.09	4.21	2.97	4.47	7.24	8.48	9.05	9.60	60.84
1956-57	4.14	5.16	3.53	1.35	1.59	2.57	3.73	3.66	6.48	9.53	9.84	8.29	59.87
1957-58	3.19	2.15	1.76	2.25	1.62	1.59	4.00	5.75	6.41	7.81	7.11	6.52	50.16
23-year mean	5.67	3.71	2.44	2.27	2.41	3.38	4.09	5.65	6.96	9.80	9.75	8.37	64.50

[1] The values during these years (excepting July, August, and September of 1938, for which there are direct data) were interpolated from data obtained at the "Old" Tanbark Climatic Station location on the basis of a comparison of later data taken simultaneously at both locations.

SAN DIMAS EXPERIMENTAL FOREST
Tanbark Flat Climatic Station, Elevation 2,800 feet

Evaporation Data--San Dimas Pan

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -	Surface inches		- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -
1934-35[1]	--	--	--	--	--	--	--	--	--	9.68	8.62	8.66	--
1935-36[1]	5.15	3.48	2.85	2.49	2.11	3.24	4.60	6.58	8.89	9.48	9.44	7.73	66.04
1936-37[1]	5.13	3.56	2.52	2.13	2.06	3.16	4.25	5.64	8.44	10.09	9.82	7.70	64.50
1937-38[1]	5.63	2.38	1.96	1.95	1.16	2.61	4.06	5.92	7.20	9.63	9.49	8.29	60.28
1938-39	4.89	5.06	2.59	2.57	2.88	3.03	4.52	5.33	7.68	9.44	10.22	6.63	64.84
1939-40	5.55	3.84	2.96	1.86	2.14	3.79	4.20	6.76	8.19	10.48	10.16	7.63	67.56
1940-41	5.95	3.58	2.18	1.61	--	--	--	--	--	--	--	--	--
5-year mean[2]	5.27	3.66	2.58	2.20	2.07	3.17	4.33	6.05	8.08	9.82	9.83	7.60	64.66

[1] The values during these years (excepting July, August, and September of 1938, for which there are direct data) were interpolated from data obtained at the "Old" Tanbark Climatic Station location on the basis of a comparison of later data taken simultaneously at both locations.

[2] 5-year mean for the years 1935-1940.

SAN DIMAS EXPERIMENTAL FOREST
Tanbark Flat Climatic Station, Elevation 2,800 feet

Evaporation Data--Taylor Black Pan

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -	Surface inches	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -
1936-37	--	--	--	--	--	--	--	--	10.30	12.07	12.04	10.89	--
1937-38	9.07	6.04	4.50	4.40	4.16	4.77	7.56	9.92	9.33	11.59	11.05	10.56	92.95
1938-39	7.26	8.81	6.29	4.25	3.08	6.73	8.19	6.60	9.67	12.21	11.32	8.55	92.96
1939-40	8.62	5.52	4.84	2.73	4.41	6.20	7.26	8.49	9.57	12.43	12.18	9.39	91.64
1940-41	8.65	5.61	5.42	2.76	2.44	3.88	5.46	6.82	8.40	11.41	9.30	8.52	78.67
1941-42	7.22	5.34	3.35	3.66	3.95	7.56	5.91	8.56	10.11	14.60	12.43	10.77	93.46
1942-43	7.59	5.31	4.70	4.43	4.33	4.00	5.72	9.17	9.45	12.25	11.30	11.51	89.76
1943-44	7.20	5.92	2.61	3.26	2.84	6.24	5.88	7.17	6.91	10.75	12.32	9.37	80.47
1944-45	7.38	3.35	3.69	3.32	3.12	4.28	7.58	7.14	7.04	11.83	11.36	9.24	79.33
1945-46	6.21	4.97	3.20	5.26	4.00	4.60	6.79	4.91	9.63	10.79	11.94	10.30	82.60
1946-47	5.65	3.00	2.90	4.16	3.43	4.30	5.75	7.05	7.94	12.75	10.57	9.93	77.43
1947-48	6.41	4.70	3.51	4.99	4.22	4.00	5.54	6.85	7.98	12.64	12.86	11.23	84.93
1948-49	6.72	5.67	2.75	2.43	2.35	4.27	6.46	6.37	9.00	11.05	11.38	10.84	79.29
1949-50	6,56	5,59	2,89	2,10	3.55	5.03	5.63	6.97	8.86	11.18	13.32	10.34	82.02
1950-51	9.16	6.21	4.12	2.59	3.39	5.82	4.40	8.18	9.22	12.24	12.08	11.84	89.25
1951-52	7.40	3.61	2.01	1.73	3.37	3.41	4.81	8.60	7.48	10.50	10.51	8.46	71.89
1952-53	7.27	2.68	1.98	3.28	4.41	5.33	4.92	7.40	7.86	11.31	10.96	9.86	77.26
1953-54	7.41	4.09	4.51	2.36	4.67	3.46	5.82	7.70	7.65	10.04	9.25	9.10	76.06
17-year mean	7.40	5.08	3.72	3.39	3.63	4.93	6.10	7.52	8.59	11.74	11.42	9.99	83.51

SAN DIMAS EXPERIMENTAL FOREST
San Gabriel Divide Climatic Station, Elevation 4,350 feet

Evaporation Data--Weather Bureau Pan

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
						Surface inches							
1935-36	--	--	--	--	--	--	--	--	9.21	9.85	9.46	8.50	--
1936-37	--	--	--	--	--	--	--	--	--	--	10.34	8.20	--
1937-38	6.81	3.60	--	--	--	--	--	9.06	7.77	10.35	8.71	8.01	--
1938-39	5.07	4.88	3.03	2.29	2.58	3.87	6.06	6.61	9.15	10.74	11.30	7.06	72.64
1939-40	6.75	4.53	2.93	1.93	2.05	4.72	5.08	7.69	9.78	10.51	10.61	7.49	74.07
1940-41	5.86	3.67	2.00	1.15	1.00	2.11	3.20	6.35	6.18	9.76	8.05	7.24	56.57
1941-42	5.08	3.49	1.55	2.68	2.56	4.33	2.58	6.49	8.57	11.74	10.50	9.00	68.57
1942-43	6.52	4.19	3.99	3.50	3.03	2.73	4.38	7.40	7.31	9.84	8.87	7.74	69.50
5-year mean[1]	5.86	4.15	2.70	2.31	2.24	3.55	4.26	6.91	8.20	10.52	9.87	7.71	68.28

[1] 5-year mean for the years 1938-43.

SAN DIMAS EXPERIMENTAL FOREST

Fern Canyon Climatic Station, Elevation 5,100 feet

Evaporation Data--Weather Bureau Pan

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
	- - - - - - - - - - - - - - - - - - - Surface inches -												
1936-37	--	--	--	--	--	--	--	7.70	9.15	10.45	11.06	9.10	--
1937-38	6.70	--	--	--	--	--	3.28	4.68	7.81	7.34	--	--	--
1938-39	--	--	4.50	2.00	2.00	4.14	6.94	8.58	9.88	11.04	11.21	6.51	--
1939-40	8.64	5.68	4.16	1.53	1.11	4.46	5.24	8.66	10.92	11.15	11.11	7.35	80.01
1940-41	No records --												
1941-42	--	--	--	3.00	3.01	4.14	2.99	6.73	9.43	12.00	10.37	9.38	--
1942-43	6.45	4.07	3.60	3.35	3.91	3.05	4.73	7.92	7.71	10.61	8.75	8.59	72.74

MOUNTAIN TEMPERATURES

DATA FROM THE SAN DIMAS EXPERIMENTAL FOREST

BY LYLE F. REIMANN

EXPERIMENT STATION
AUG 4 1971
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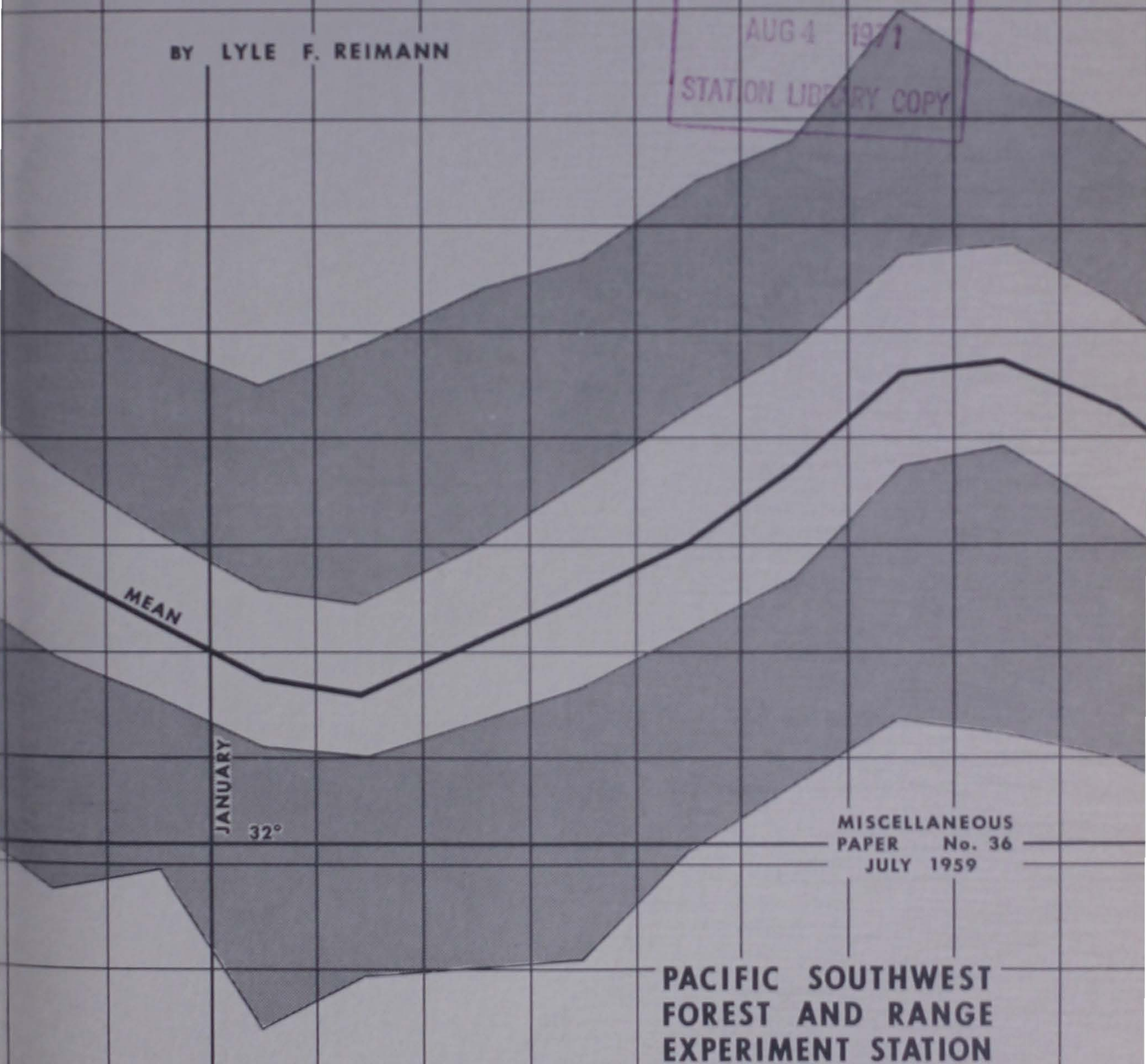

MISCELLANEOUS
PAPER No. 36
JULY 1959

PACIFIC SOUTHWEST
FOREST AND RANGE
EXPERIMENT STATION
BERKELEY - - - CALIFORNIA

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

MOUNTAIN TEMPERATURES

Twenty-five Years of Data from the San Dimas Experimental Forest

By Lyle F. Reimann

Miscellaneous Paper No. 36

July 1959

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION

ACKNOWLEDGMENT

The San Dimas Experimental Forest is a field unit of the Pacific Southwest Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture, maintained in cooperation with the State of California, Division of Forestry.

These records were made possible through the efforts of many staff members. Particular acknowledgment is made to Everett L. Hamilton, who was in charge of climatological research at the San Dimas Experimental Forest for many years, and to Lowell A. Andrews, who supervised the collection of most of these records.

Studies reported here were
conducted in cooperation with

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF FORESTRY

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THE AUTHOR: Lyle Reimann has been a member of the San Dimas Experimental Forest staff since 1938. For the past 10 years he supervised the compilation of all climatic, hydrologic and related records. Prior to his present assignment he was a member of the field staff on the experimental forest.

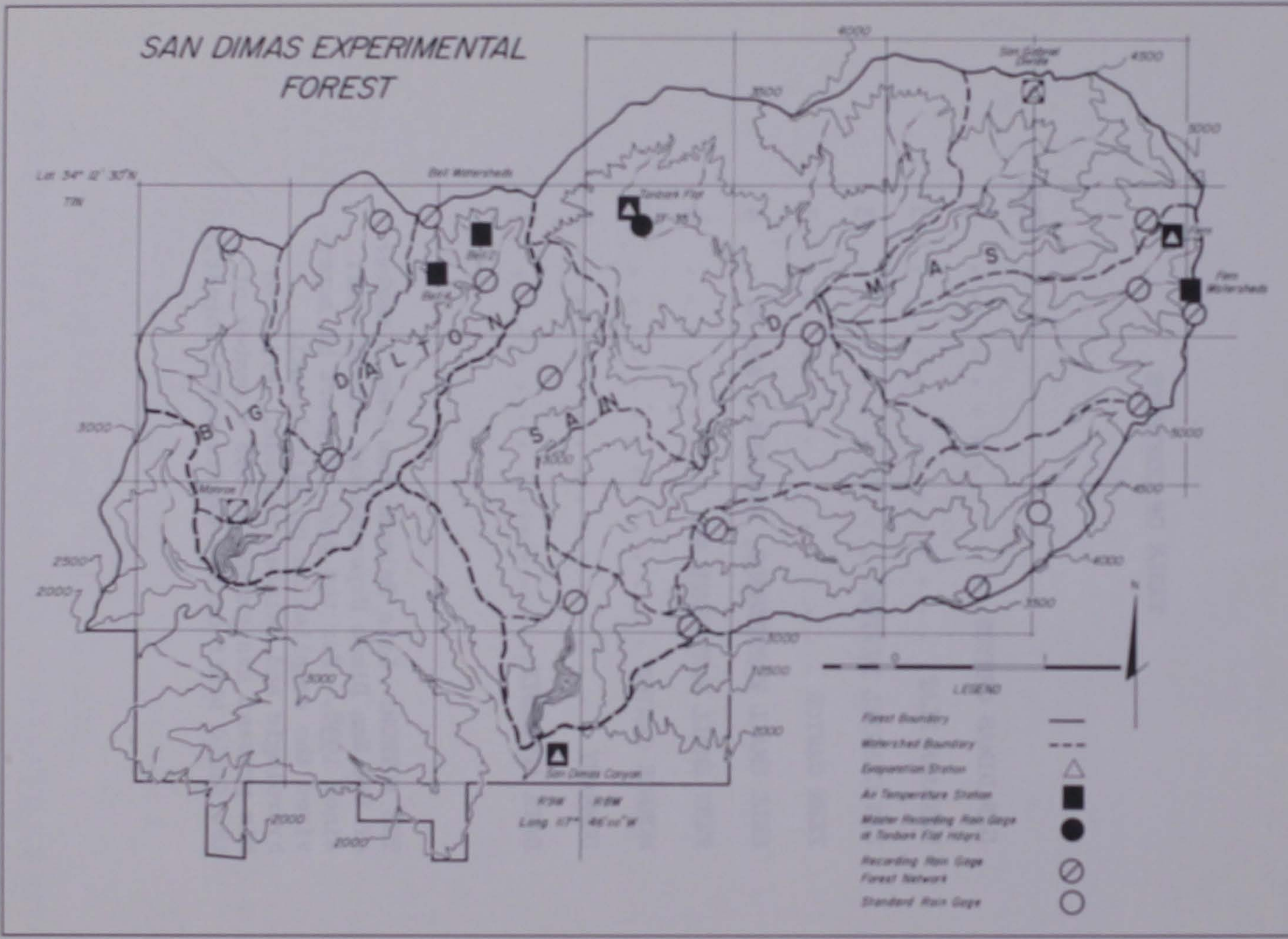
SAN DIMAS EXPERIMENTAL FOREST
Lat 34° 12' 30"N
T1N
Bell Watersheds
Bell 2
Bell 4
Tanbark Flat
BIG DALTON
SAN DIMAS
San Gabriel Divide
Fern Watersheds
Monroe
San Dimas Canyon
R9W
R8W
Long 117° 46'00"W
2000
2500
3000
3500
4000
4500
5000
0
1
N
LEGEND
Forest Boundary
Watershed Boundary
Evaporation Station
Air Temperature Station
Master Recording Rain Gage at Tanbark Flat Hdqrs.
Recording Rain Gage Forest Network
Standard Rain Gage

Figure 1.--San Dimas Experimental Forest in the San Gabriel mountains of southern California showing climatic stations and present rain gage locations.

MOUNTAIN TEMPERATURES

Twenty-five Years of Data from the San Dimas Experimental Forest

Lyle F. Reimann

The vertical distribution and variation of atmospheric temperature on southern slopes of the San Gabriel mountains in California are presented in this report. The data were collected in conjunction with watershed management research conducted by the Forest Service in cooperation with the California Division of Forestry on the San Dimas Experimental Forest, 30 miles northeast of Los Angeles.

Climatic stations were located at different elevations to obtain temperature gradients from the foothills to front range peaks (fig. 1). Records of air temperature were obtained at eight stations by means of a thermograph supplemented by Weather Bureau type maximum and minimum thermometers exposed in louvered instrument shelters (figs. 2 to 7 incl.).

San Dimas Canyon

The first station in lower San Dimas Canyon was installed in October 1933 at 1,450 feet elevation (latitude 34°09', longitude 117°46') in an opening in chaparral vegetation within a basin-like pocket. Exposure was northwest. This station was operated until April 12, 1937. This station was not considered properly located. On April 17, 1936 a new station, more representative of the area, was established 800 feet north-northeast of the first station on a bench at 1,500 feet elevation in a firebreak cut through chaparral vegetation (fig. 2). Exposure was southwest. Records were collected at the second station until November 7, 1944.

Temperatures given for the period October 1933 through April 1936 for the first station (Appendix page 9) are corrected for the second station by means of regression analysis of records from both stations during 1936-37, for the 12-month period both stations were operated.

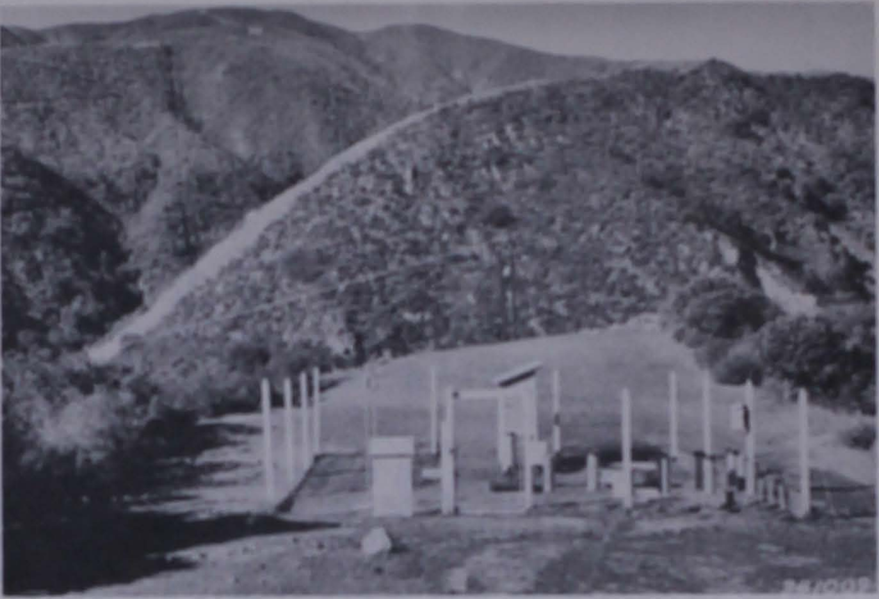

Figure 2.--San Dimas Canyon climatic station

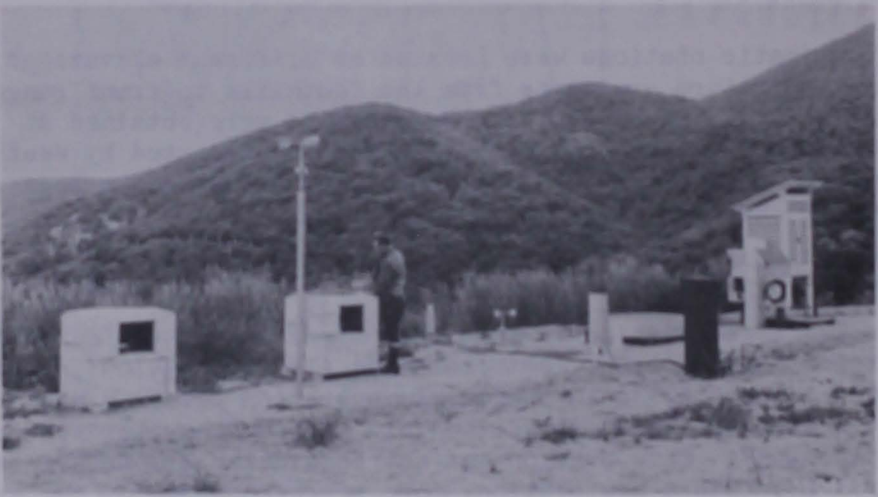

Figure 3.--Tanbark Flat climatic station, 1940.

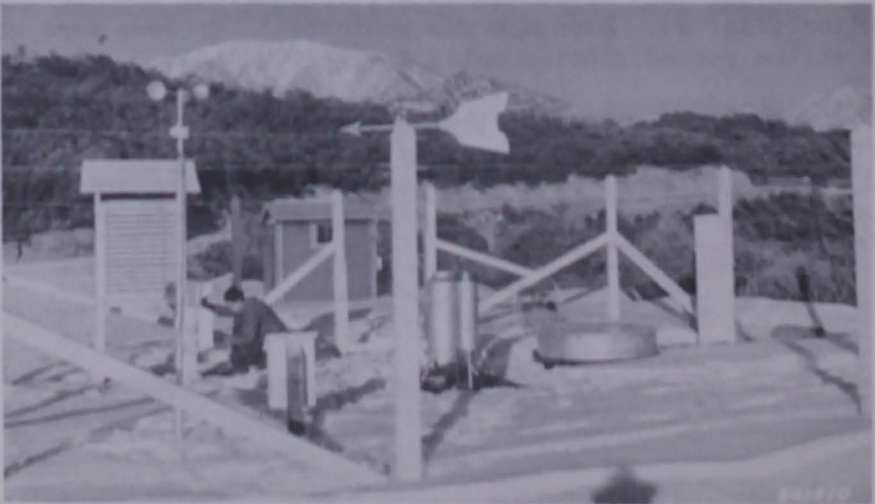

Figure 4.--San Gabriel Divide climatic station

Tanbark Flat

This station is in the north fork of San Dimas Canyon, near the Tanbark Flat field headquarters of the San Dimas Experimental Forest. The first station was installed in October 1933 at 2,725 feet elevation (latitude 34°12', longitude 117°46') in an opening in chaparral vegetation with a south exposure. The station was operated until October 31, 1938. On May 13, 1937 a new station was installed, 1,100 feet north by west of the first station at 2,800 feet elevation. It has a southern exposure and is in an area surrounded by shrub vegetation (fig. 3). This station is currently in operation.

Temperatures given for the period October 1933 through July 1937 (Appendix page 12) are corrected for the new station by regression analysis of records from both stations during the period May 1937 through October 1938, when both stations were operated.

San Gabriel Divide

The station was installed in October 1933 at 4,350 feet elevation (latitude 34°13', longitude 117°43') in the east fork of San Dimas Canyon, in an opening in the chaparral on a point near the crest of a ridge (fig. 4). Exposure was due south. Records were collected at this station until November 1943. Records were interrupted at times during the winter season by freezing temperatures and snow.

Fern Canyon

Fern Canyon is a main tributary to the east fork of San Dimas Canyon. The first station was installed in October 1933 at 5,050 feet elevation (latitude 34°12', longitude 117°42') near a saddle on a main ridge. This station was operated until September 27, 1937. On September 28, 1936 a new station was installed 1,050 feet west by north of the first station at 5,100 feet elevation in an area surrounded by chaparral vegetation (fig. 5). Exposure was south. The station and surrounding brush cover were destroyed by fire in November 1938. The area was fairly well revegetated by sprouting shrubs within the next three years. Records were collected at this station until November 1944.

Temperatures given for the period October 1933 through September 1936 (Appendix page 23) are corrected for the new station based upon regression analysis of records during the time both stations were operated October 1936 through September 1937.

Bell Small Watersheds Nos. 2 and 4

Comparative observations of local temperature were made at two stations on the 2,800 foot contour trail (figs. 6 and 7) in the Bell Watersheds for 6 years, October 1936 through September 1942. The Bell Watersheds are upper tributaries to Bell Canyon, a main fork of Big Dalton Canyon. The stations were surrounded by undisturbed brush cover and had similar aspects to the southeast.

Fern Small Watershed No. 1

Supplementary to observations at the Fern Canyon station (elevation 5,100 feet), air temperatures were obtained at a station located in one of the Fern Small Watersheds for a 7-year period, October 1937 through September 1944. This station was located one-half mile due south of the Fern Canyon station and at 5,200 feet elevation with a western exposure. The surrounding vegetation was mostly interior live oak (Quercus wislizenii) which had reached tree form after escaping fire for more than 50 years. The area was subsequently burned over in November 1938 and the station was destroyed. It was resumed in January 1939 and the records were continued into 1944.

Monroe Canyon

Air temperature observations were taken for 2 years at an installation in Monroe Canyon, a main tributary to Big Dalton Canyon, at 1,700 feet elevation. These observations were for comparison with the San Dimas Canyon station (1,500 feet). The Monroe station was situated near the bottom of the narrow lower canyon, whereas the San Dimas station was on a bench on the side of a much larger canyon. Both stations were within the valley fog belt.

SUMMARY

The data presented are for varying periods of time. The master climatic station near the Tanbark Field Headquarters has been in continuous operation from 1933 to date. The other stations were operated until a reasonable climatic trend was established. To facilitate comparisons between stations, term means of 25, 10, 11, and 6 years were computed and are set forth on the summary sheet, (Appendix page 33). Temperatures listed are monthly and annual means, except the absolute temperatures, which are the highest and lowest in the designated period.

All means were derived from 2-hour tabulations of the thermograph trace. These 2-hour tabulations were totaled and averaged for days, weeks, months, years, and periods. The daily and weekly data are too numerous for publication. The mean maxima, and mean minima were averaged from all of the daily observations in each month.

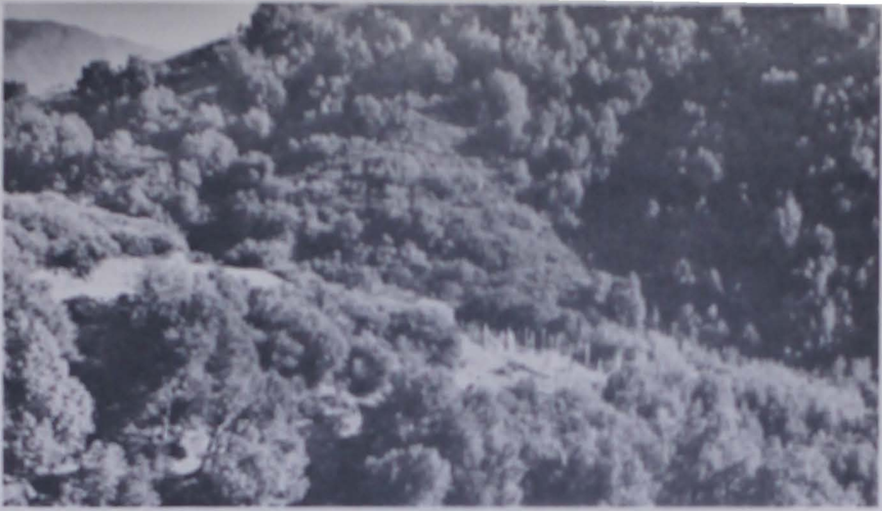

Figure 5.--Fern Canyon climatic station

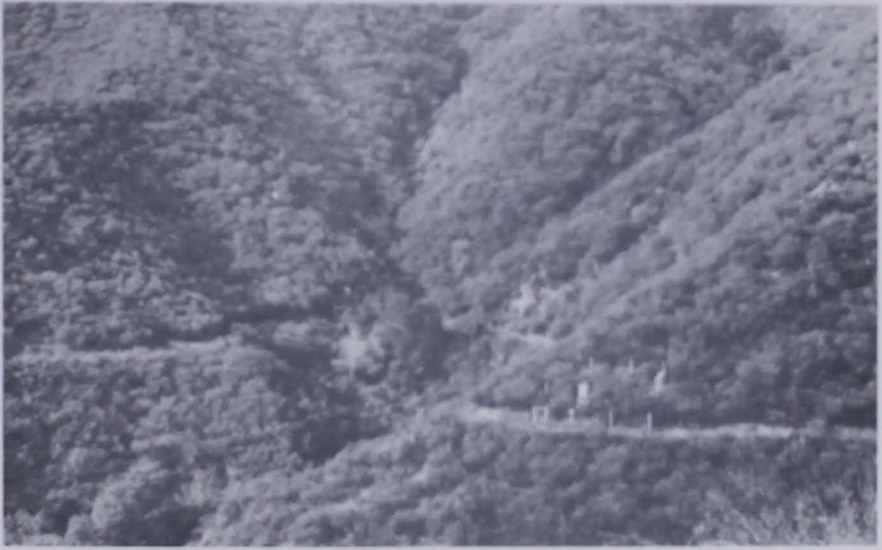

Figure 6.--Bell Small Watershed No. 2 climatic station

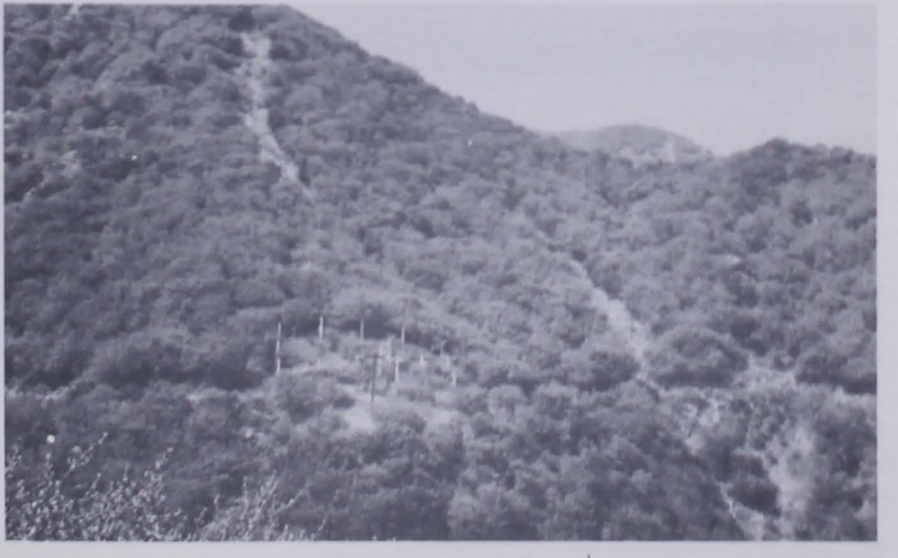

Figure 7.--Bell Small Watershed No. 4 climatic station

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SAN DIMAS EXPERIMENTAL FOREST
Air Temperature, °F.

San Dimas Canyon Climatic Station, Elevation 1,500 feet

	Absolute		Mean			Absolute		Mean		
Month	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean
			1933-34					1934-35		
October	85.0	40.5	68.5	44.1	54.0	103.0	43.5	78.0	52.0	63.3
November	87.0	27.5	73.9	44.3	55.4	85.5	41.5	69.0	45.9	55.0
December	74.5	29.0	59.8	38.1	47.2	74.0	31.5	62.6	42.3	51.6
January	69.5	31.0	61.6	37.3	47.0	81.0	26.5	60.9	39.0	48.9
February	70.5	37.0	61.3	39.7	49.8	81.0	28.5	64.7	41.3	52.5
March	82.5	39.0	72.1	43.5	56.8	81.5	28.5	60.4	36.7	48.0
April	93.0	36.5	78.2	48.3	61.1	84.0	33.5	71.1	45.7	56.5
May	99.0	42.0	82.2	50.3	64.9	86.0	41.5	73.7	48.1	59.0
June	92.0	47.0	77.2	51.9	63.3	98.5	48.0	84.3	51.0	65.3
July	112.5	48.5	92.0	57.4	72.3	110.0	48.0	90.7	55.8	70.9
August	99.0	50.0	91.3	56.6	71.3	111.0	52.0	93.4	59.4	74.0
September	103.0	43.5	89.0	55.8	69.5	101.5	46.5	91.2	55.4	69.8
Annual	112.5	27.5	75.7	47.3	59.4	111.0	26.5	75.0	47.7	59.6
			1935-36					1936-37		
October	92.5	41.0	75.3	44.7	59.8	106.0	46.0	78.7	51.4	63.5
November	86.0	31.0	71.0	41.5	54.8	90.0	38.0	76.0	47.8	60.1
December	76.5	25.5	61.5	36.5	50.2	75.0	34.0	62.6	41.2	51.2
January	76.0	33.0	65.4	40.2	53.7	58.0	21.0	49.8	30.6	39.6
February	69.0	30.5	58.9	39.9	51.9	75.5	32.0	62.8	39.2	49.9
March	87.0	28.0	65.8	39.2	54.0	79.0	33.0	66.8	42.4	53.4
April	93.5	36.0	74.8	45.0	58.1	89.0	32.5	73.6	44.3	58.2
May	90.5	41.0	79.9	51.5	63.5	97.0	44.0	76.5	49.7	61.4
June	103.5	41.0	87.8	54.8	68.8	102.0	44.0	85.7	52.0	67.2
July	112.0	51.0	94.5	61.7	74.6	106.0	49.0	94.1	55.8	73.4
August	103.0	49.5	94.9	60.2	74.0	104.5	48.0	95.5	59.5	74.9
September	106.0	51.0	90.3	56.6	69.4	106.0	47.0	95.9	58.6	73.2
Annual	112.0	25.5	76.8	47.6	61.1	106.0	21.0	76.5	47.7	60.5

SAN DIMAS EXPERIMENTAL FOREST
Air Temperature, °F.

San Dimas Canyon Climatic Station, Elevation 1,500 feet

	Absolute		Mean			Absolute		Mean		
Month	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max	Min.	Mean
			1937-38					1938-39		
October	97.0	45.0	83.6	53.2	66.7	91.0	42.0	78.8	50.0	63.1
November	87.0	40.5	72.8	46.1	58.0	81.5	32.0	73.1	43.0	57.0
December	81.0	37.0	68.5	46.0	56.3	89.0	36.0	69.0	45.0	55.8
January	79.0	34.0	67.4	42.8	53.9	74.0	36.0	63.7	40.3	51.3
February	73.5	34.0	60.9	42.1	51.7	77.0	26.0	58.3	35.6	47.0
March	80.5	34.5	63.6	41.2	51.7	85.0	33.0	64.5	41.3	52.2
April	89.5	37.0	70.1	44.5	57.1	92.5	36.5	72.2	46.9	60.0
May	101.5	36.5	76.5	47.9	61.8	93.0	41.0	74.7	47.1	60.8
June	93.0	46.0	81.3	50.2	64.5	99.5	45.5	86.5	50.0	68.2
July	102.5	45.0	90.5	55.7	72.0	110.0	49.0	92.2	55.8	72.7
August	105.5	50.0	93.0	58.6	74.0	101.5	48.5	94.3	57.6	74.9
September	107.0	50.0	93.0	59.8	74.5	104.5	47.0	89.9	60.0	73.9
Annual	107.0	34.0	76.9	49.1	61.9	110.0	26.0	76.5	47.8	61.5
			1939-40					1940-41		
October	95.0	43.0	82.4	51.4	66.1	101.0	40.0	84.2	51.5	65.6
November	84.0	41.0	76.4	48.1	61.1	86.0	35.0	72.7	43.8	56.5
December	88.0	34.5	73.6	45.9	58.8	84.0	29.0	68.7	45.1	55.9
January	80.5	33.0	62.7	41.9	52.6	71.0	36.5	63.0	40.8	51.2
February	75.0	34.0	64.7	41.1	52.7	75.0	34.0	64.4	42.7	52.3
March	80.0	36.0	69.7	43.8	56.4	82.5	36.0	66.6	41.2	52.8
April	93.0	37.0	72.5	45.5	59.2	80.0	34.0	66.9	41.0	53.1
May	97.0	39.5	81.1	48.0	64.3	94.0	41.0	80.0	50.1	64.7
June	95.0	44.0	83.5	49.3	66.7	96.0	42.5	80.8	47.5	63.3
July	104.0	44.0	92.0	53.2	72.3	104.0	48.5	94.3	54.6	73.4
August	106.5	47.5	91.3	53.1	71.4	102.0	46.0	88.7	54.9	70.3
September	98.0	46.0	86.2	51.4	67.8	96.0	43.0	85.9	49.8	66.0
Annual	106.5	33.0	78.1	47.8	62.5	104.0	29.0	76.4	47.0	60.5

SAN DIMAS EXPERIMENTAL FOREST

Air Temperature, °F.

San Dimas Canyon Climatic Station, Elevation 1,500 feet

	Absolute		Mean			Absolute		Mean		
Month	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean
			1941-42					1942-43		
October	96.0	40.5	77.3	49.9	62.7	95.5	39.5	79.0	50.7	62.8
November	90.0	31.0	76.6	47.8	60.9	89.5	35.0	74.0	45.8	58.0
December	89.0	27.5	63.0	39.5	50.4	83.0	34.0	67.8	42.2	53.3
January	78.5	27.0	66.7	40.5	52.4	82.5	30.0	64.1	42.6	52.9
February	71.0	27.0	63.2	36.5	49.1	82.0	30.0	63.8	43.6	53.2
March	84.5	29.0	68.6	39.1	53.6	76.5	38.5	65.9	45.2	55.1
April	81.0	35.0	66.9	42.8	53.5	89.0	34.0	72.0	46.8	58.4
May	85.5	35.0	76.9	44.6	60.1	92.0	38.5	79.0	49.8	62.6
June	100.0	43.0	84.5	48.4	64.7	100.0	41.5	82.2	50.7	65.2
July	108.0	49.0	96.6	56.0	75.0	110.0	46.5	92.1	54.2	71.6
August	101.0	46.0	91.8	55.1	71.9	101.5	49.0	91.9	57.4	72.3
September	91.0	43.5	88.0	50.4	67.1	109.0	53.0	93.9	59.0	73.9
Annual	108.0	27.0	76.8	45.9	60.2	110.0	30.0	77.2	49.6	61.6
			1943-44					11-year period, 1933-44		
October	103.0	40.0	80.8	52.4	64.3	106.0	39.5	78.8	50.1	62.9
November	85.0	40.0	75.8	49.4	59.7	90.0	27.5	73.8	45.8	57.9
December	76.0	36.0	60.7	43.2	50.4	89.0	25.5	65.3	42.3	52.8
January	84.5	33.5	62.6	42.6	50.4	84.5	21.0	62.5	39.9	50.4
February	74.0	33.0	58.1	39.4	46.9	82.0	26.0	61.9	40.1	50.6
March	80.0	30.5	66.1	43.6	53.1	87.0	28.0	66.4	41.6	53.4
April	84.0	36.0	67.5	50.1	53.4	93.0	32.5	71.4	45.5	57.1
May	90.5	41.0	73.6	47.6	58.9	101.5	35.0	77.6	48.6	62.0
June	95.5	41.5	75.2	49.8	60.7	103.5	41.0	82.6	50.5	65.3
July	99.0	43.0	86.2	50.2	65.8	112.5	43.0	92.3	55.5	72.2
August	108.5	48.0	93.3	56.7	72.7	111.0	46.0	92.7	57.2	72.9
September	108.5	47.5	85.2	54.8	67.1	109.0	43.0	89.9	55.6	70.2
Annual	108.5	30.5	73.8	48.3	58.7	112.5	21.0	76.3	47.8	60.7

SAN DIMAS EXPERIMENTAL FOREST
Air Temperature, °F.

Tanbark Flat Climatic Station, Elevation 2,800 feet

Month	Absolute		Mean			Absolute		Mean		
	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean
			1933-34					1934-35		
October	87.0	34.5	75.1	48.2	61.1	89.5	40.5	71.6	48.3	59.9
November	86.0	28.0	73.1	45.6	59.0	80.0	36.5	61.1	41.5	50.9
December	73.0	32.0	61.7	39.4	50.7	71.0	29.0	59.5	40.4	49.2
January	68.0	33.5	62.2	39.8	51.0	75.0	25.0	58.1	37.6	47.3
February	67.0	35.5	59.5	40.3	50.7	74.0	28.0	58.9	39.2	49.1
March	78.5	39.0	70.5	45.8	59.9	74.0	28.0	55.0	36.4	45.1
April	88.0	37.5	73.6	46.0	59.9	76.0	30.5	62.0	41.1	51.0
May	99.0	37.5	77.2	46.9	62.4	86.0	36.5	64.9	44.3	54.0
June	91.0	41.5	72.9	48.7	61.0	92.0	45.0	80.2	48.9	64.5
July	104.0	49.5	87.3	59.3	73.3	96.0	47.0	83.8	55.2	69.0
August	94.5	54.5	85.8	59.3	72.5	95.5	47.5	86.1	58.8	71.9
September	92.5	45.5	81.7	55.1	68.2	94.0	45.5	85.0	56.9	69.3
Annual	104.0	28.0	73.5	47.9	60.9	96.0	25.0	68.9	45.8	56.8
			1935-36					1936-37		
October	82.0	37.5	69.3	44.7	56.8	91.5	43.0	70.8	50.1	59.4
November	75.0	30.0	61.4	37.4	48.9	80.5	35.5	66.7	44.2	54.2
December	72.5	31.0	60.0	37.7	47.8	69.0	31.5	58.6	39.7	47.1
January	70.0	29.0	60.3	36.8	46.7	58.0	19.0	45.5	30.6	35.7
February	68.5	30.0	55.2	37.6	45.9	70.5	27.0	57.7	37.2	45.8
March	77.0	30.0	63.9	40.6	51.7	71.5	31.0	60.8	40.5	49.2
April	84.0	33.5	69.1	41.7	54.1	81.0	38.0	68.4	42.9	53.8
May	84.0	38.0	75.2	45.4	59.2	89.0	42.0	70.2	47.6	59.8
June	99.0	36.5	83.4	51.9	67.1	97.5	43.5	79.2	50.9	67.1
July	101.5	46.5	87.6	61.0	73.3	95.0	48.0	84.9	56.4	72.1
August	95.0	51.5	88.6	59.5	72.9	97.0	48.5	89.2	61.4	76.6
September	100.0	45.0	84.3	54.6	68.0	98.0	47.5	84.9	58.3	72.9
Annual	101.5	29.0	71.6	45.8	57.7	98.0	19.0	69.8	46.7	57.9

SAN DIMAS EXPERIMENTAL FOREST
Air Temperature, °F.

Tanbark Flat Climatic Station, Elevation 2,800 feet

	Absolute		Mean			Absolute		Mean		
Month	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean
			1937-38					1938-39		
October	88.0	42.0	78.7	54.2	65.2	81.5	39.0	70.6	46.6	57.7
November	77.0	36.0	69.0	44.5	55.5	76.0	31.0	66.1	40.7	52.5
December	73.0	31.0	64.8	43.9	53.6	83.0	33.5	63.6	41.8	51.4
January	74.0	31.5	63.0	40.9	51.4	68.0	27.5	57.1	36.5	46.1
February	67.0	28.0	55.3	37.6	46.0	70.0	22.0	52.8	31.6	41.6
March	69.5	29.0	56.8	36.5	45.5	79.0	27.0	60.5	39.2	48.6
April	84.0	33.5	64.4	41.2	52.3	89.0	32.0	69.9	45.2	56.9
May	100.0	32.0	71.8	46.1	58.2	86.0	37.0	69.4	45.3	56.3
June	91.0	42.0	76.2	50.3	61.8	92.5	41.0	79.5	51.4	64.6
July	99.5	46.0	86.7	58.2	71.4	100.5	43.5	86.7	59.2	71.8
August	98.5	46.0	86.3	59.5	71.0	93.5	50.0	89.9	62.9	74.6
September	94.0	49.0	85.8	60.5	71.3	98.0	42.0	83.1	60.7	70.3
Annual	100.0	28.0	71.7	47.9	58.7	100.5	22.0	70.9	46.8	57.8
			1939-40					1940-41		
October	86.5	37.5	75.0	52.2	62.6	91.0	37.0	76.3	50.1	63.4
November	79.0	39.0	71.1	47.2	58.0	79.5	33.0	66.8	42.5	54.7
December	80.5	30.5	68.1	44.7	55.0	79.0	33.0	64.0	42.9	52.9
January	68.0	31.0	60.2	41.3	49.5	69.5	33.0	57.4	38.4	47.9
February	69.0	31.0	58.8	38.1	48.0	70.0	32.0	58.6	40.4	49.8
March	75.0	31.0	64.3	40.9	52.8	76.0	34.0	61.6	39.6	51.0
April	87.0	35.0	64.7	41.6	53.6	74.0	32.0	60.1	39.0	51.0
May	89.0	38.5	73.0	46.5	59.9	87.0	39.0	72.3	48.7	61.2
June	92.0	42.0	79.2	51.1	65.0	88.5	41.5	73.0	47.7	60.8
July	98.0	44.0	84.6	54.8	70.0	96.0	49.5	85.5	58.5	72.5
August	99.5	45.0	86.2	57.1	71.9	93.0	47.0	80.6	55.5	67.8
September	93.0	44.0	79.4	51.8	65.2	90.0	41.5	77.7	48.8	62.9
Annual	99.5	30.5	72.1	47.3	59.4	96.0	32.0	69.6	46.2	58.1

SAN DIMAS EXPERIMENTAL FOREST
Air Temperature, °F.

Tanbark Flat Climatic Station, Elevation 2,800 feet

	Absolute		Mean			Absolute		Mean		
Month	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean
			1941-42					1942-43		
October	86.0	39.5	68.2	46.5	55.9	90.0	38.5	74.5	48.8	60.1
November	83.0	30.5	69.4	46.6	56.2	82.0	29.5	69.1	43.4	54.7
December	76.5	28.0	56.7	36.7	45.3	76.5	29.5	62.2	38.6	48.9
January	78.0	26.5	60.8	39.5	48.5	78.5	27.5	59.4	40.9	49.7
February	63.0	25.0	55.7	34.7	43.6	78.0	26.5	61.7	39.8	49.8
March	79.0	29.5	61.6	38.0	48.8	76.5	32.5	59.6	40.3	49.5
April	74.0	32.0	59.5	40.6	48.0	83.0	30.5	65.5	42.5	53.4
May	79.0	34.5	68.6	43.6	54.4	86.5	32.5	72.0	45.8	58.4
June	92.5	40.5	77.8	49.5	62.0	92.5	40.0	74.1	47.5	60.5
July	97.5	49.5	90.3	61.5	74.4	101.5	42.0	85.1	54.9	69.7
August	97.0	43.0	86.4	59.0	79.7	94.5	47.0	84.4	56.0	69.3
September	93.0	43.5	81.6	55.1	66.9	100.0	49.5	87.0	58.8	72.2
Annual	97.5	25.0	69.8	46.0	56.3	101.5	26.5	71.3	46.4	58.1
			1943-44					1944-45		
October	94.0	34.5	75.4	50.8	63.7	84.0	41.0	74.3	48.8	61.9
November	78.0	33.0	69.7	46.0	54.5	72.0	33.0	59.3	39.9	47.6
December	69.0	30.5	56.7	38.7	46.6	73.0	29.5	62.7	40.3	49.5
January	79.0	28.0	58.7	38.0	46.9	73.0	26.5	60.4	38.1	46.8
February	71.0	28.0	53.0	34.3	42.7	77.0	29.0	57.2	39.8	47.9
March	74.0	27.0	61.3	39.4	49.8	75.0	28.0	55.8	36.2	45.9
April	79.0	30.5	62.4	38.4	51.4	85.0	29.0	65.8	41.2	53.5
May	82.0	35.0	68.7	44.0	53.8	83.0	34.5	66.9	43.0	55.0
June	98.0	38.5	69.8	46.0	57.9	95.0	41.0	73.0	49.6	61.2
July	94.0	39.0	82.0	50.8	66.0	96.5	54.0	87.1	59.4	72.7
August	103.0	48.5	88.0	57.5	72.1	97.0	43.5	85.8	59.4	71.8
September	100.0	41.0	83.4	54.6	67.3	96.0	41.0	82.5	57.2	69.1
Annual	103.0	27.0	69.2	44.9	56.1	97.0	26.5	69.3	46.0	55.3

SAN DIMAS EXPERIMENTAL FOREST
Air Temperature, °F.

Tanbark Flat Climatic Station, Elevation 2,800 feet

	Absolute		Mean			Absolute		Mean		
Month	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean
			1945-46					1946-47		
October	91.0	41.5	73.7	49.1	60.3	83.5	34.0	69.8	44.3	56.1
November	84.5	30.5	65.2	40.1	51.5	79.0	32.5	61.7	40.5	49.5
December	78.5	27.0	57.9	37.8	47.2	76.5	29.5	62.0	40.7	49.7
January	77.0	27.5	60.4	36.8	46.9	76.0	27.0	60.8	35.8	46.6
February	73.0	27.5	58.6	35.4	46.7	76.0	31.5	65.6	41.0	52.0
March	78.0	29.5	60.0	38.0	48.8	78.0	33.0	62.6	41.2	51.4
April	87.0	34.0	69.1	43.9	56.7	88.0	31.0	68.0	43.5	55.9
May	82.5	39.0	65.4	45.1	54.4	94.0	39.0	72.6	47.0	60.0
June	90.0	41.5	80.5	52.2	66.1	87.0	42.0	75.5	48.9	62.5
July	95.5	48.5	86.4	58.6	72.3	100.5	49.0	88.8	56.7	73.7
August	100.0	50.5	88.2	58.8	73.3	100.5	40.0	83.2	54.3	69.1
September	97.5	43.5	86.9	57.3	71.4	100.5	42.0	86.6	58.2	72.4
Annual	100.0	27.0	71.1	46.1	58.0	100.5	27.0	71.5	46.2	58.3
			1947-48					1948-49		
October	94.5	40.0	74.9	47.6	60.0	90.5	34.0	72.9	48.3	60.6
November	80.0	29.0	63.7	38.6	49.6	77.0	30.0	68.0	41.4	53.2
December	78.0	25.0	59.9	36.0	46.6	72.0	21.5	56.0	32.6	42.8
January	80.5	25.0	67.7	40.0	52.0	60.0	18.0	44.1	27.0	34.6
February	75.0	24.0	57.5	33.6	44.4	69.0	23.0	50.0	29.5	39.6
March	69.0	26.0	56.3	32.6	43.4	67.0	27.0	54.4	31.9	42.3
April	85.5	29.0	63.9	39.6	51.0	85.5	30.5	66.2	40.9	53.5
May	85.0	32.0	68.3	41.2	54.3	85.5	35.0	65.4	43.2	53.8
June	96.0	38.0	75.5	47.2	60.7	89.0	39.5	77.7	49.3	64.0
July	94.0	46.0	83.3	53.6	69.3	94.0	44.5	84.0	53.6	69.0
August	100.5	48.0	85.8	53.8	70.4	94.0	38.0	84.4	52.9	68.9
September	103.5	41.0	84.8	56.5	71.6	100.0	39.5	86.2	54.4	70.9
Annual	103.5	24.0	70.2	43.4	56.2	100.0	18.0	67.5	42.1	54.5

SAN DIMAS EXPERIMENTAL FOREST
Air Temperature, °F.

Tanbark Flat Climatic Station, Elevation 2,800 feet

	Absolute		Mean			Absolute		Mean		
Month	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean
			1949-50					1950-51		
October	87.0	25.5	71.0	45.9	57.7	102.0	42.0	82.7	51.8	65.6
November	86.0	34.0	74.7	48.9	60.3	87.0	31.5	74.3	47.3	59.4
December	80.0	26.0	61.1	38.3	48.7	84.5	33.5	70.3	44.4	55.5
January	75.0	22.0	53.9	32.4	42.3	80.5	27.0	59.6	35.4	46.3
February	76.0	26.0	65.2	39.7	50.0	82.0	23.0	60.8	35.5	46.7
March	79.5	28.0	64.9	38.3	49.2	80.0	24.0	65.3	38.8	51.2
April	87.5	31.0	67.4	42.8	53.8	84.0	31.0	64.3	41.4	52.0
May	87.0	28.5	70.6	42.5	55.4	96.0	32.5	73.0	43.2	57.4
June	101.0	36.0	79.2	46.0	62.0	94.5	40.5	77.8	46.9	61.8
July	101.0	48.0	86.5	56.1	70.8	100.5	45.0	90.0	57.9	73.8
August	106.0	46.0	91.2	56.8	73.6	97.0	46.5	88.5	56.6	71.6
September	107.0	40.5	81.6	52.4	65.8	100.5	46.0	90.1	57.6	73.0
Annual	107.0	22.0	73.0	45.1	57.5	102.0	23.0	74.8	46.5	59.6
			1951-52					1952-53		
October	96.5	35.0	77.1	48.6	61.6	98.0	37.5	85.4	53.4	67.3
November	83.0	30.5	66.9	41.4	52.2	82.0	28.0	61.9	37.0	48.3
December	68.5	26.0	56.3	35.0	44.5	78.5	29.0	59.0	35.6	45.4
January	72.0	22.5	55.4	32.6	42.5	84.0	30.0	67.7	41.7	53.0
February	75.0	26.0	60.4	35.7	46.5	78.5	26.5	63.9	36.9	48.5
March	78.0	26.0	53.8	33.3	42.7	80.5	25.5	64.4	35.4	48.5
April	82.5	32.0	64.6	41.8	52.6	80.5	26.0	64.1	38.0	50.2
May	86.5	37.0	77.4	47.0	61.6	83.0	31.0	67.8	40.0	53.2
June	92.0	39.5	73.0	45.4	58.6	95.0	35.0	76.3	47.4	61.5
July	96.0	49.0	89.0	57.3	72.7	100.0	52.0	92.0	59.1	74.7
August	98.5	48.0	90.0	58.4	72.8	99.0	45.0	88.9	54.6	70.4
September	98.0	37.5	88.1	57.9	71.8	105.0	41.0	89.4	54.7	70.6
Annual	98.5	22.5	71.0	44.6	56.7	105.0	25.5	73.5	44.5	57.7

SAN DIMAS EXPERIMENTAL FOREST
Air Temperature, °F.

Tanbark Flat Climatic Station, Elevation 2,800 feet

	Absolute		Mean			Absolute		Mean		
Month	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean
			1953-54					1954-55		
October	95.5	33.0	78.6	48.4	61.8	95.5	37.5	79.6	47.8	61.5
November	87.0	30.5	71.0	43.6	55.3	84.5	28.0	72.4	45.1	56.9
December	81.5	29.0	66.5	39.0	50.5	78.5	26.0	62.3	36.6	46.8
January	78.5	30.0	59.8	35.8	46.6	75.0	26.0	53.9	32.5	41.6
February	83.0	30.0	70.9	42.8	56.1	78.0	24.0	59.8	34.7	45.5
March	79.0	28.0	59.5	36.5	47.1	80.0	30.5	65.4	37.9	50.3
April	90.5	37.0	70.3	44.5	56.6	79.0	28.5	65.9	38.0	51.5
May	85.0	34.0	74.6	45.7	59.1	89.0	32.0	67.5	42.8	55.3
June	90.5	33.0	77.8	48.3	62.5	92.5	38.0	77.7	47.4	61.8
July	99.0	52.5	91.1	60.1	74.9	96.0	43.0	85.6	53.3	68.7
August	102.0	41.0	84.5	50.8	67.0	107.0	52.5	92.8	61.0	76.1
September	96.5	45.5	87.3	53.5	68.6	108.5	42.0	89.4	55.7	71.3
Annual	102.0	28.0	74.3	45.8	58.8	108.5	24.0	72.8	44.4	57.3
			1955-56					1956-57		
October	95.0	38.0	81.7	48.2	63.5	85.0	28.5	72.3	44.1	56.2
November	85.5	28.5	67.4	41.4	52.8	89.5	31.0	75.1	43.3	57.6
December	76.0	25.5	60.6	38.1	47.2	80.5	29.5	68.4	40.4	52.5
January	79.0	30.0	62.3	38.2	48.5	70.0	20.0	52.9	34.2	42.7
February	72.0	24.0	56.1	31.6	42.7	83.5	28.0	64.1	41.9	51.4
March	84.0	29.0	68.4	38.0	52.4	79.5	30.0	62.5	38.9	49.9
April	85.5	28.0	63.6	39.1	50.9	82.5	30.5	65.1	40.6	51.8
May	92.0	36.5	69.2	44.0	56.0	84.0	36.0	65.9	42.5	55.4
June	99.0	42.5	83.0	49.6	65.7	103.0	46.0	77.1	54.1	68.4
July	97.5	40.0	86.5	54.0	69.6	101.0	45.0	92.1	56.4	74.0
August	104.0	43.5	85.4	52.0	67.6	99.0	41.0	88.9	55.6	71.7
September	100.5	46.5	92.6	58.3	73.9	102.5	42.0	86.1	53.3	68.1
Annual	104.0	24.0	73.1	44.5	57.6	103.0	20.0	73.1	45.5	58.2

SAN DIMAS EXPERIMENTAL FOREST
Air Temperatures, °F.

Tanbark Flat Climatic Station, Elevation 2,800 feet

Month	Absolute		Mean		
	Maximum	Minimum	Maximum	Minimum	Mean
			1957-58		
October	83.0	35.5	69.1	45.4	56.1
November	78.0	30.0	64.0	38.0	48.9
December	81.0	33.0	66.8	40.4	51.4
January	74.0	29.5	63.3	37.7	49.0
February	81.5	32.0	63.0	39.6	49.5
March	70.5	26.0	55.4	35.3	44.5
April	91.5	32.0	68.7	42.5	54.9
May	85.5	39.0	76.0	47.6	61.2
June	93.0	39.0	79.8	49.4	63.8
July	103.0	45.5	86.4	53.9	70.0
August	98.5	50.0	90.5	59.2	73.6
September	98.5	44.0	88.6	56.7	71.3
Annual	103.0	26.0	72.7	45.5	57.9

SAN DIMAS EXPERIMENTAL FOREST

Tanbark Flat Air Temperature Summary, °F

	Absolute		Mean			Absolute		Mean		
Month	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean
	10-year period 1933-43					11-year period 1933-44				
October	91.5	37.0	73.0	49.0	60.2	94.0	34.5	73.2	49.1	60.5
November	86.0	29.5	67.4	43.4	54.5	86.0	29.5	67.6	43.6	54.5
December	83.0	28.0	61.9	40.6	50.2	83.0	28.0	61.4	40.4	49.9
January	78.5	19.0	58.4	38.2	47.4	79.0	19.0	58.4	38.2	47.3
February	78.0	22.0	57.4	37.6	47.0	78.0	22.0	57.0	37.3	46.6
March	79.0	27.0	61.5	39.8	50.2	79.0	27.0	61.4	39.7	50.2
April	89.0	30.5	65.7	42.2	53.4	89.0	30.5	65.4	41.8	53.2
May	100.0	32.0	71.5	46.0	58.4	100.0	32.0	71.2	45.8	58.0
June	99.0	36.5	77.6	49.8	63.4	99.0	36.5	76.8	49.4	62.9
July	104.0	42.0	86.2	57.9	71.8	104.0	39.0	85.9	57.3	71.2
August	99.5	43.0	86.4	58.9	72.8	103.0	43.0	86.5	58.8	72.8
September	100.0	41.5	83.0	56.1	68.7	100.0	41.0	83.1	55.9	68.6
Annual	104.0	19.0	70.9	46.7	58.2	104.0	19.0	70.8	46.5	58.0
	6-year period 1936-42					25-year period 1933-58				
October	91.5	37.0	73.3	50.0	60.7	102.0	25.5	74.7	48.5	60.6
November	83.0	30.5	68.2	44.3	55.2	89.5	28.0	67.6	42.6	53.7
December	83.0	28.0	62.6	41.6	50.9	84.5	21.5	61.8	39.2	49.1
January	78.0	19.0	57.3	37.9	46.5	84.0	18.0	58.6	36.7	46.4
February	70.5	22.0	56.5	36.6	45.8	83.5	22.0	59.2	37.1	47.2
March	79.0	27.0	60.9	39.1	49.3	84.0	24.0	61.0	38.0	48.8
April	89.0	32.0	64.5	41.8	52.6	91.5	26.0	65.9	41.5	53.2
May	100.0	32.0	70.9	46.3	58.3	100.0	28.5	70.6	44.8	57.2
June	97.5	40.5	77.5	50.2	63.6	103.0	33.0	77.2	49.0	62.9
July	100.5	43.5	86.5	58.1	72.0	104.0	39.0	86.9	56.8	71.6
August	99.5	43.0	86.4	59.2	73.6	107.0	38.0	87.2	57.2	71.9
September	98.0	41.5	82.1	55.9	68.3	108.5	37.5	85.4	56.0	69.8
Annual	100.5	19.0	70.7	46.8	58.0	108.5	18.0	71.5	45.7	57.7

SAN DIMAS EXPERIMENTAL FOREST

Air Temperature, °F.

San Gabriel Divide Climatic Station, Elevation 4350 feet

	Absolute		Mean			Absolute		Mean		
Month	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean
			1933-34					1934-35		
October	84.0	48.0	76.8	57.0	64.8	91.0	38.0	74.8	55.1	63.2
November	84.0	29.0	72.3	51.9	60.4	78.5	36.5	65.2	47.4	55.1
December	75.0	31.0	62.6	46.0	53.2	76.0	31.0	58.0	42.2	49.7
January	70.0	35.0	63.3	45.9	53.6	72.0	19.5	55.6	38.9	46.3
February	70.0	35.0	61.2	43.3	50.8	79.0	28.0	58.4	40.1	48.4
March	83.0	43.0	74.5	55.1	63.3	74.5	23.5	54.4	35.4	44.2
April	85.0	41.0	73.8	52.5	62.1	76.0	27.0	61.6	40.8	50.8
May	94.0	38.0	77.9	54.2	64.9	83.0	34.0	63.8	44.2	54.0
June	97.5	38.0	74.5	51.4	62.1	93.0	52.0	82.6	60.6	70.9
July	110.0	48.0	90.9	66.1	77.3	102.5	44.0	86.2	64.3	73.8
August	100.5	59.0	89.7	66.5	76.4	103.5	47.0	89.4	65.7	76.9
September	97.0	39.5	82.9	60.4	69.8	99.0	58.0	88.6	64.8	74.6
Annual	110.0	29.0	75.1	54.3	63.3	103.5	19.5	69.9	50.0	59.0
			1935-36					1936-37		
October	86.5	42.0	72.7	49.9	61.1	92.0	38.5	71.8	57.2	64.4
November	73.5	29.5	62.8	44.1	53.4	80.0	35.0	67.7	55.2	61.1
December	72.5	33.0	58.7	41.3	50.8	70.0	29.5	56.8	42.7	51.1
January	72.0	31.5	60.2	41.2	51.3	52.5	13.5	43.8	29.5	37.8
February	62.5	27.0	52.1	37.7	46.2	70.5	24.0	56.4	39.4	49.2
March	79.0	20.0	63.5	44.3	54.5	74.0	25.0	58.0	40.3	50.3
April	85.0	32.0	67.3	45.3	57.4	83.0	30.0	68.3	40.8	53.5
May	89.0	36.0	75.0	52.3	63.7	92.0	37.0	73.4	51.1	59.9
June	98.0	37.5	84.5	60.2	72.5	98.0	40.5	81.0	57.8	67.1
July	105.0	47.5	89.1	66.1	78.5	100.5	55.0	90.1	69.5	76.4
August	102.0	56.0	91.3	68.4	80.5	100.0	57.0	92.5	70.9	77.6
September	99.5	42.0	87.7	62.8	74.4	99.0	46.0	88.0	63.2	72.2
Annual	105.0	20.0	72.2	51.2	62.1	100.5	13.5	70.7	51.5	60.1

SAN DIMAS EXPERIMENTAL FOREST
Air Temperature, °F.

San Gabriel Divide Climatic Station, Elevation 4350 feet

	Absolute		Mean			Absolute		Mean		
Month	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean
			1937-38					1938-39		
October	88.5	38.0	78.6	56.0	63.7	77.5	34.5	68.7	53.2	58.8
November	77.5	36.5	68.3	47.5	54.4	69.0	27.0	61.6	45.6	51.9
December	75.5	28.0	61.5	44.1	50.2	79.0	30.5	58.4	44.8	49.8
January	70.0	29.0	59.4	41.8	47.8	63.5	21.0	51.2	38.0	43.8
February	62.5	28.0	48.2	33.6	38.6	65.0	19.5	46.8	31.9	38.3
March	67.5	28.0	57.6	35.9	43.7	74.0	26.0	57.3	39.4	46.8
April	84.0	29.0	63.8	42.3	50.9	80.0	21.0	68.8	50.0	58.3
May	89.5	31.5	70.4	48.6	57.3	91.0	38.0	68.8	50.0	58.5
June	85.5	39.5	77.7	55.5	64.3	93.0	40.0	79.0	57.8	68.1
July	98.0	50.0	88.3	65.2	74.2	100.0	49.0	84.4	63.3	73.2
August	101.0	43.0	87.9	63.8	72.4	99.0	59.0	88.4	67.7	76.8
September	93.0	50.0	86.9	63.8	71.7	98.0	44.0	77.6	58.0	66.0
Annual	101.0	28.0	70.9	49.9	57.6	100.0	19.5	67.7	50.1	57.6
			1939-40					1940-41		
October	85.0	37.5	72.4	52.6	61.1	91.0	35.0	75.3	53.5	62.9
November	82.0	43.0	69.3	51.2	58.8	79.0	33.0	64.9	46.8	54.7
December	80.0	30.0	65.3	46.4	54.7	78.0	31.0	56.8	42.9	49.3
January	73.5	31.5	56.7	42.0	48.9	65.0	32.5	51.2	38.6	42.8
February	67.5	29.5	56.9	38.9	47.3	68.0	32.0	52.5	39.6	45.4
March	80.0	29.0	65.5	44.9	54.0	70.0	30.5	55.9	38.3	45.7
April	86.0	30.0	64.8	45.4	54.4	75.0	29.0	59.2	38.6	47.2
May	87.0	40.0	75.8	54.5	64.5	87.0	37.5	73.8	50.6	60.9
June	97.0	45.0	85.4	60.9	72.3	89.5	38.0	75.8	51.6	63.5
July	100.0	46.0	88.1	61.8	74.0	100.0	48.5	89.7	65.0	76.3
August	103.0	55.0	91.1	65.3	77.1	93.0	49.0	84.5	60.4	71.0
September	99.0	46.0	81.0	55.4	65.9	91.5	43.0	80.3	55.0	66.4
Annual	103.0	29.0	72.8	51.7	61.2	100.0	29.0	68.4	48.5	57.3

SAN DIMAS EXPERIMENTAL FOREST
Air Temperature, °F.

San Gabriel Divide Climatic Station, Elevation 4350 feet

Month	Absolute		Mean			Absolute		Mean		
	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean
			1941-42					1942-43		
October	87.0	33.0	68.4	47.9	56.5	91.0	36.0	74.5	53.7	62.3
November	82.0	23.0	69.2	49.4	57.9	81.0	33.0	70.2	53.8	60.7
December	74.5	26.0	56.0	38.3	45.9	74.0	35.0	62.0	44.7	52.2
January	73.0	23.0	60.9	42.4	50.0	78.0	29.0	57.2	41.2	47.8
February	70.0	24.5	55.4	35.4	43.5	78.5	24.0	60.8	42.1	50.4
March	78.0	23.5	61.5	39.8	49.2	74.0	34.0	59.1	41.5	49.2
April	73.0	29.0	59.9	39.4	48.2	83.0	26.0	66.1	44.5	54.8
May	93.0	33.0	70.5	45.8	57.0	91.0	35.0	76.3	51.0	62.7
June	101.0	44.0	82.1	55.3	67.6	96.5	36.5	75.7	54.0	64.1
July	102.0	57.5	94.2	68.2	79.8	102.5	51.5	89.9	64.7	76.1
August	102.0	46.5	91.3	64.9	76.2	95.0	54.5	87.2	62.1	73.1
September	95.0	47.5	85.9	60.4	71.0	99.0	46.5	88.7	63.9	74.7
Annual	102.0	23.0	71.4	49.0	58.7	102.5	24.0	72.4	51.5	60.7
			10-year period, 1933-43							
October	92.0	33.0	73.4	53.6	57.1					
November	84.0	23.0	67.1	49.3	58.2					
December	80.0	26.0	59.6	43.4	46.5					
January	78.0	13.5	55.9	39.9	49.8					
February	79.0	19.5	54.9	38.2	44.2					
March	83.0	20.0	60.7	41.5	49.2					
April	86.0	21.0	65.4	43.6	48.9					
May	94.0	31.5	72.6	50.2	57.6					
June	101.0	36.5	79.8	56.5	67.2					
July	110.0	44.0	89.1	65.4	79.4					
August	103.5	43.0	89.4	65.6	75.9					
September	99.5	39.5	84.7	60.8	71.4					
Annual	110.0	13.5	71.1	50.8	58.9					

SAN DIMAS EXPERIMENTAL FOREST

Air Temperature, °F.

Fern Canyon Climatic Station, Elevation 5100 feet

	Absolute		Mean			Absolute		Mean		
Month	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean
	1933-34					1934-35				
October	79.5	40.0	69.5	52.6	59.1	83.5	34.0	68.2	51.8	57.5
November	80.5	24.0	67.5	48.7	56.2	68.5	36.0	59.6	45.0	49.6
December	71.5	25.0	59.4	41.8	48.9	69.0	29.0	56.5	41.5	46.7
January	69.0	31.0	59.5	42.0	49.2	68.0	20.0	53.2	38.4	43.5
February	68.0	32.0	55.5	39.5	46.1	71.5	26.0	55.2	39.8	45.2
March	80.0	39.0	71.0	51.5	60.7	71.5	24.0	50.7	33.1	41.3
April	83.5	37.0	70.6	48.1	58.9	71.5	28.0	61.9	43.5	50.9
May	89.5	37.5	74.5	52.0	62.8	78.0	35.5	66.1	47.2	54.6
June	91.0	36.5	73.4	50.7	62.3	88.5	49.5	81.4	61.8	70.5
July	102.0	55.0	89.0	64.4	76.7	92.5	42.5	85.2	62.7	72.8
August	95.0	59.5	88.2	64.4	75.9	94.0	57.0	88.6	68.5	76.5
September	92.5	35.0	82.7	58.7	70.0	95.0	51.5	84.5	63.4	72.6
Annual	102.0	24.0	71.8	51.0	60.6	95.0	20.0	67.6	49.8	56.9
	1935-36					1936-37				
October	78.0	36.0	66.2	48.0	57.6	87.0	31.5	69.8	47.9	57.9
November	72.0	30.0	58.3	41.2	50.3	77.0	38.0	65.2	44.7	54.6
December	64.5	31.0	50.5	35.3	43.8	68.0	21.0	52.7	37.7	44.4
January	68.5	29.0	54.3	36.7	45.7	47.0	13.0	36.6	22.2	28.2
February	59.0	23.5	48.7	34.8	43.1	66.5	22.0	52.4	34.2	41.6
March	76.5	16.0	61.0	41.6	51.2	70.5	23.5	55.3	36.5	43.6
April	81.0	40.5	68.1	45.8	59.0	80.0	27.5	64.5	40.5	50.3
May	84.5	33.5	75.6	53.2	66.5	92.0	37.0	74.1	47.9	60.2
June	96.0	34.5	81.2	58.8	71.7	92.0	43.0	82.5	57.2	68.4
July	101.0	39.5	88.6	62.9	76.0	97.5	59.0	89.3	65.7	77.0
August	99.5	53.0	87.1	62.2	75.0	99.0	55.0	90.7	65.9	77.8
September	96.0	38.0	80.8	56.5	70.0	96.5	43.0	86.0	60.4	72.6
Annual	101.0	16.0	68.5	48.2	59.3	99.0	13.0	68.3	46.8	56.5

SAN DIMAS EXPERIMENTAL FOREST
Air Temperature, °F.

Fern Canyon Climatic Station, Elevation 5100 feet

Month	Absolute		Mean			Absolute		Mean		
	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean
			1937-38					1938-39		
October	86.0	38.0	76.9	54.5	64.4	76.0	34.0	67.2	46.1	55.2
November	75.0	33.0	66.7	45.0	55.3	68.0	26.0	61.7	40.7	50.6
December	74.0	25.0	61.1	43.3	52.7	78.5	31.0	57.2	41.1	48.4
January	70.0	26.0	58.8	40.0	49.1	62.0	28.5	52.5	35.3	43.4
February	64.0	23.0	50.0	33.6	41.8	64.0	20.0	46.0	28.7	37.5
March	64.0	24.0	51.6	32.8	42.3	74.0	26.0	56.8	38.0	46.7
April	81.0	26.0	61.5	39.8	50.5	72.0	27.0	65.9	46.0	55.7
May	85.0	29.0	67.5	45.7	56.9	85.5	35.0	69.1	46.8	57.6
June	91.0	37.0	75.6	53.4	64.0	86.0	39.0	77.1	54.3	65.5
July	97.0	46.0	86.5	63.0	73.6	95.0	49.0	84.0	62.7	72.7
August	96.0	51.0	86.3	62.4	72.8	96.0	59.0	86.4	65.9	75.1
September	90.0	57.0	84.8	61.1	71.0	89.0	36.0	77.4	56.8	65.4
Annual	97.0	23.0	69.1	48.0	58.0	96.0	20.0	66.9	47.0	56.3
			1939-40					1940-41		
October	78.5	35.0	65.5	49.9	57.7	84.0	31.0	72.5	50.2	60.5
November	72.0	40.0	64.0	47.6	52.0	75.0	29.5	60.3	40.7	51.3
December	73.0	28.0	62.7	45.2	53.1	74.0	27.5	57.7	40.1	49.3
January	65.5	30.5	53.8	38.9	45.8	62.0	29.5	50.8	34.8	43.2
February	61.0	27.0	51.9	35.2	42.8	63.0	29.0	51.4	35.8	44.5
March	72.5	26.5	59.7	40.8	49.3	66.5	28.0	54.5	36.9	45.5
April	77.0	30.0	58.9	41.3	49.4	70.0	25.5	54.3	36.1	45.9
May	80.0	39.0	71.6	61.3	60.7	80.5	33.0	67.7	48.3	58.6
June	92.0	45.0	83.0	60.6	71.4	82.5	33.0	72.3	51.9	62.6
July	94.0	46.0	84.7	61.5	72.0	93.0	43.0	84.4	62.0	72.3
August	96.0	55.0	87.3	64.9	75.3	87.0	46.0	79.4	57.9	68.0
September	95.0	44.0	77.3	54.0	64.3	87.0	38.0	74.9	51.2	62.9
Annual	96.0	26.5	68.5	49.4	57.9	93.0	25.5	65.1	45.6	55.5

SAN DIMAS EXPERIMENTAL FOREST
Air Temperature, °F.

Fern Canyon Climatic Station, Elevation 5100 feet

	Absolute		Mean			Absolute		Mean		
Month	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean
			1941-42					1942-43		
October	83.0	28.0	61.8	43.0	50.2	83.0	29.0	68.9	49.6	56.9
November	77.0	22.5	63.4	44.6	52.0	78.0	28.0	63.5	44.0	52.3
December	70.0	21.0	50.6	33.8	41.2	70.0	26.5	56.0	37.7	45.4
January	70.0	18.0	55.6	38.5	45.0	73.0	22.0	50.7	34.6	41.4
February	66.0	20.0	50.4	31.6	38.7	76.0	22.0	57.2	39.0	47.1
March	71.0	20.0	56.2	36.4	44.5	68.0	33.0	56.2	39.5	46.8
April	68.0	29.0	54.9	36.5	44.0	77.0	24.0	62.1	43.4	52.0
May	86.0	31.0	63.9	43.4	52.4	86.0	34.5	71.3	49.9	59.5
June	90.0	44.0	76.6	54.4	64.3	84.5	33.0	70.5	50.5	59.3
July	96.0	54.0	87.2	65.9	74.6	97.5	49.0	83.0	61.7	71.2
August	94.5	40.0	85.1	62.2	71.6	91.0	51.5	83.5	60.6	70.8
September	89.0	40.5	79.4	57.4	66.1	93.0	55.5	83.9	61.3	71.0
Annual	96.0	18.0	65.5	45.7	53.8	97.5	22.0	67.3	47.7	56.2
			1943-44					11-year period, 1933-44		
October	87.5	31.0	70.8	51.8	58.5	87.5	28.0	68.8	49.6	57.8
November	73.0	30.0	63.7	46.7	54.1	80.0	22.5	63.1	44.4	52.5
December	63.5	27.5	48.1	34.8	40.9	78.5	21.0	55.7	39.3	46.8
January	70.0	24.0	50.8	35.4	42.0	73.0	13.0	52.4	36.1	43.3
February	67.0	23.5	44.6	29.2	36.2	76.0	20.0	51.2	34.7	42.3
March	68.0	17.0	53.3	34.8	43.0	80.0	16.0	56.9	38.3	46.8
April	71.5	26.5	54.7	36.7	45.0	83.5	24.0	61.6	41.6	51.0
May	75.0	27.0	64.9	44.8	55.5	92.0	27.0	69.7	48.2	58.6
June	91.5	29.0	65.3	45.0	54.2	96.0	29.0	76.2	54.4	65.0
July	88.0	49.5	79.9	59.8	69.1	102.0	39.5	85.6	62.9	73.5
August	99.5	55.0	84.5	63.3	72.9	99.5	40.0	86.1	63.5	73.8
September	92.5	40.5	80.3	59.9	69.2	96.5	35.0	81.1	58.2	68.6
Annual	99.5	17.0	63.4	45.3	53.4	102.0	13.0	67.4	47.7	56.8

SAN DIMAS EXPERIMENTAL FOREST
Air Temperature, °F

Bell Watershed No. 2 Climatic Station, Elevation 2,800 feet

	Absolute		Mean			Absolute		Mean		
Month	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean
			1936-37					1937-38		
October	93.0	48.0	78.2	56.1	65.1	94.0	43.5	83.0	58.3	66.6
November	87.0	42.0	74.2	53.2	62.0	82.5	41.0	72.0	49.2	56.6
December	74.0	30.0	61.5	43.5	51.0	79.5	33.5	66.9	47.0	53.6
January	56.0	22.0	47.6	31.1	38.4	80.5	34.0	65.8	44.8	51.9
February	71.0	30.0	59.8	39.9	48.6	72.0	32.0	57.0	40.1	45.9
March	76.5	30.5	62.3	42.9	50.9	74.0	33.0	58.7	39.0	45.9
April	83.0	35.0	67.3	45.7	55.4	86.0	34.0	61.2	44.6	52.0
May	92.0	44.0	70.1	50.8	59.4	93.0	35.5	70.9	50.0	57.4
June	96.0	46.0	78.8	55.8	65.5	91.0	46.0	75.8	53.3	61.1
July	98.0	50.0	88.6	65.3	74.2	103.0	45.5	87.0	62.5	71.5
August	100.0	56.0	91.7	65.4	75.8	104.5	50.0	88.2	62.3	71.3
September	103.0	51.0	89.0	63.3	74.1	100.5	56.0	88.8	63.9	72.3
Annual	103.0	22.0	72.5	51.1	60.1	104.5	32.0	73.1	51.3	58.9
			1938-39					1939-40		
October	94.5	41.0	71.3	50.8	59.1	94.0	43.0	80.5	56.8	65.1
November	78.0	36.0	67.7	46.4	55.2	85.5	47.0	77.0	53.9	61.5
December	89.0	36.0	68.4	49.1	56.8	87.5	34.5	73.4	49.3	57.4
January	73.0	35.0	60.6	42.1	50.4	74.0	37.0	62.3	45.3	49.5
February	74.0	26.0	55.5	36.8	45.2	72.0	34.5	60.2	41.8	47.2
March	84.0	34.0	68.5	47.3	56.5	78.0	35.0	67.8	45.8	52.9
April	90.0	32.0	71.9	51.6	60.4	88.0	36.0	68.8	47.6	54.5
May	89.0	41.0	70.6	51.2	59.5	90.0	44.0	73.9	49.9	59.2
June	89.5	45.0	80.4	57.0	67.8	93.0	47.0	83.9	58.1	68.2
July	102.5	48.0	87.3	63.1	73.6	101.5	50.0	90.1	63.0	74.0
August	98.0	54.0	90.1	66.5	76.8	101.0	48.0	92.5	64.7	75.9
September	102.5	48.0	84.0	61.6	71.3	93.0	50.0	85.2	58.9	68.9
Annual	102.5	26.0	73.1	52.1	61.2	101.5	34.5	76.4	53.0	61.3

SAN DIMAS EXPERIMENTAL FOREST
Air Temperature, °F.

Bell Watershed No. 2 Climatic Station, Elevation 2,800 feet

	Absolute		Mean			Absolute		Mean		
Month	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean
			1940-41					1941-42		
October	98.0	39.0	80.6	55.9	66.6	93.1	39.5	72.5	50.7	60.7
November	83.5	38.0	69.9	48.6	57.5	91.0	38.0	75.2	52.2	62.2
December	85.0	35.0	67.0	47.6	55.6	81.5	32.0	62.4	42.0	50.7
January	71.0	38.0	60.6	43.3	50.3	81.0	29.5	66.0	44.8	53.7
February	73.0	38.0	61.3	44.3	51.6	68.5	31.0	60.7	39.4	49.2
March	78.0	35.5	64.0	44.0	52.9	81.0	30.0	65.7	42.8	53.5
April	75.0	34.5	61.8	41.9	52.4	78.0	33.5	62.3	43.2	52.0
May	87.0	39.5	73.1	52.7	62.5	98.0	39.0	71.0	47.8	58.7
June	94.0	43.0	70.9	50.0	61.4	96.0	44.0	79.3	54.0	65.7
July	100.0	52.0	87.5	63.1	73.9	105.0	58.0	92.0	66.1	77.8
August	94.0	51.0	85.4	61.3	71.4	99.0	47.5	88.6	63.4	74.6
September	93.0	48.0	82.2	57.0	68.1	97.0	48.0	85.3	59.7	71.4
Annual	100.0	34.5	72.1	50.9	60.4	105.0	29.5	73.5	50.6	60.9
		6-year period 1936-42								
October	98.0	39.0	77.7	54.8	63.9					
November	91.0	36.0	72.7	50.6	59.2					
December	89.0	30.0	66.6	46.4	54.2					
January	81.0	22.0	60.5	41.9	49.0					
February	74.0	26.0	59.1	40.4	47.9					
March	84.0	30.0	64.5	43.6	52.1					
April	90.0	32.0	65.5	45.8	54.4					
May	98.0	35.5	71.6	50.4	59.4					
June	96.0	43.0	78.2	54.7	64.9					
July	106.0	45.5	88.8	63.8	74.2					
August	104.0	48.0	89.4	63.9	74.3					
September	103.0	48.0	85.7	60.7	71.0					
Annual	106.0	22.0	73.5	51.5	60.5					

SAN DIMAS EXPERIMENTAL FOREST

Air Temperature, °F.

Bell Watershed No. 4 Climatic Station, Elevation 2,800 feet

	Absolute		Mean			Absolute		Mean		
Month	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean
			1936-37					1937-38		
October	93.0	47.0	75.6	55.8	64.5	91.5	46.0	80.8	60.6	69.3
November	84.0	40.0	72.6	52.7	61.2	79.0	41.0	70.6	51.2	59.0
December	73.0	26.0	59.8	42.3	49.9	78.0	34.0	66.5	48.8	56.1
January	56.0	22.5	44.8	28.6	35.7	77.5	29.0	64.9	47.1	54.3
February	70.5	33.5	59.4	40.8	49.3	71.0	31.0	55.9	40.6	47.0
March	75.5	30.0	63.0	44.1	52.2	71.0	33.0	58.0	39.7	47.5
April	82.0	32.0	68.8	47.0	57.6	84.0	34.0	64.5	45.6	53.9
May	91.0	43.0	70.7	51.3	60.5	90.5	42.0	70.2	51.1	59.4
June	94.0	46.0	78.6	57.3	66.9	90.0	45.0	75.0	54.2	63.0
July	96.0	49.0	88.0	67.2	77.9	101.0	51.0	85.3	64.5	74.2
August	97.0	56.0	89.6	68.5	78.7	106.5	49.0	86.8	63.8	74.1
September	99.0	50.0	86.2	65.1	75.7	99.0	52.0	87.1	66.7	76.2
Annual	99.0	22.5	71.5	51.8	60.9	106.5	29.0	72.2	52.9	61.3
			1938-39					1939-40		
October	85.0	40.0	73.1	54.1	61.9	90.5	43.0	77.5	59.4	67.0
November	80.0	35.0	68.8	49.6	57.6	81.0	48.0	71.5	55.7	63.2
December	86.0	35.0	65.4	48.3	55.1	85.0	36.0	70.0	52.0	59.4
January	71.0	35.0	58.7	41.8	49.0	72.5	38.0	60.9	46.5	52.1
February	72.0	25.0	53.2	35.8	43.5	73.0	36.0	59.9	43.5	50.5
March	81.0	33.0	60.0	42.2	49.9	75.0	36.0	65.5	47.0	54.8
April	82.0	35.5	68.8	49.1	57.8	87.5	37.0	66.0	47.0	55.8
May	86.0	40.0	67.7	48.9	56.9	90.0	43.0	73.9	53.8	62.9
June	93.0	44.0	78.5	55.1	66.5	92.0	46.0	80.7	58.3	68.6
July	100.0	48.5	85.6	62.3	72.8	98.5	48.0	86.9	63.6	74.8
August	95.0	53.0	88.4	66.6	76.5	99.0	49.0	88.6	65.2	76.4
September	101.5	50.5	83.7	62.2	71.5	91.0	50.0	81.3	59.7	68.8
Annual	101.5	25.0	71.1	51.4	60.0	99.0	36.0	73.7	54.4	62.9

SAN DIMAS EXPERIMENTAL FOREST
Air Temperature, °F

Bell Watershed No. 4 Climatic Station, Elevation 2,800 feet

Month	Absolute		Mean			Absolute		Mean		
	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean
			1940-41					1941-42		
October	95.0	40.0	79.3	56.5	67.0	91.0	39.0	71.3	49.1	60.3
November	81.0	38.5	68.8	49.7	58.3	89.0	37.5	72.7	50.7	61.7
December	83.0	36.0	65.9	48.3	56.2	80.0	32.0	60.2	39.6	50.0
January	68.0	38.0	57.7	42.7	49.4	69.5	30.0	63.4	43.2	53.1
February	74.0	38.0	59.1	43.2	50.4	70.0	30.5	58.5	37.5	48.2
March	78.0	32.0	61.8	44.0	52.0	81.0	29.0	63.3	40.8	52.7
April	73.0	34.0	60.1	40.6	50.5	73.0	32.5	61.1	40.5	50.9
May	86.0	40.0	72.7	52.8	62.6	98.0	38.5	71.7	47.5	60.0
June	89.0	43.0	72.8	51.9	62.5	100.5	43.0	79.6	53.7	67.0
July	97.0	53.5	87.7	65.3	75.8	101.5	57.5	92.2	65.3	79.7
August	96.5	50.5	82.5	60.9	70.7	98.0	45.5	88.1	63.0	76.0
September	93.0	47.0	79.2	55.3	66.8	96.0	48.0	84.7	59.7	73.1
Annual	97.0	32.0	70.7	51.0	60.3	101.5	29.0	72.3	49.3	61.1
			6-year period 1936-42							
October	95.0	39.0	76.3	55.9	65.0					
November	89.0	35.0	70.8	51.6	60.2					
December	86.0	26.0	64.6	46.5	54.4					
January	77.5	22.5	58.4	41.6	48.9					
February	74.0	25.0	57.7	40.2	48.1					
March	81.0	29.0	61.9	43.0	51.5					
April	87.5	32.0	64.9	45.0	54.4					
May	98.0	38.5	71.2	50.9	60.4					
June	100.5	43.0	77.5	55.1	65.7					
July	101.5	48.0	87.6	64.7	75.9					
August	106.5	45.5	87.3	64.7	75.4					
September	101.5	47.0	83.7	61.4	72.0					
Annual	106.5	22.5	71.9	51.8	61.1					

SAN DIMAS EXPERIMENTAL FOREST
Air Temperature, °F.

Fern Small Watershed No. 1 Climatic Station, Elevation 5,200 feet

	Absolute		Mean			Absolute		Mean		
Month	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean
			1937-38					1938-39		
October	82.5	38.0	72.6	54.5	61.7	73.0	34.0	64.9	46.6	54.4
November	71.0	33.0	62.5	44.9	52.7	67.5	27.0	60.2	40.4	50.4
December	69.0	25.5	55.9	41.7	48.5	77.0	31.0	55.7	40.8	48.2
January	63.0	27.5	54.5	39.4	46.6	60.5	21.0	51.0	35.0	43.2
February	60.0	24.0	48.9	34.8	41.3	65.5	15.0	44.4	27.7	36.0
March	61.0	26.0	49.4	33.0	40.9	73.0	25.0	55.7	37.5	46.1
April	77.0	25.0	59.3	40.7	49.8	77.0	27.0	65.7	46.6	56.0
May	83.0	29.5	65.5	47.0	56.1	84.0	35.0	68.0	47.7	57.6
June	85.5	38.0	73.5	54.9	63.3	87.0	40.0	75.8	55.3	65.7
July	93.0	49.0	82.5	64.2	72.2	91.0	51.0	82.9	63.5	72.7
August	93.0	51.0	81.5	63.8	71.3	95.0	64.0	85.4	66.5	75.2
September	93.0	58.0	80.2	62.2	69.4	89.0	41.0	72.9	56.8	65.3
Annual	93.0	24.0	65.6	48.5	56.2	95.0	15.0	65.4	47.2	56.0
			1939-40					1940-41		
October	77.0	35.0	66.8	50.4	57.6	84.0	32.5	70.7	51.7	59.6
November	70.0	37.0	64.5	49.9	55.9	71.0	30.0	59.8	43.1	50.4
December	72.0	29.0	60.7	45.1	52.2	73.0	30.0	56.5	41.9	48.4
January	65.0	31.0	52.6	39.8	45.6	60.0	30.0	50.3	36.5	42.3
February	61.0	28.5	50.0	37.2	44.2	64.0	32.0	51.2	37.3	43.3
March	71.5	27.0	57.3	42.7	50.5	68.5	30.0	54.3	38.6	44.9
April	77.0	30.0	57.5	43.5	51.1	67.0	28.0	53.8	37.8	45.2
May	81.0	40.0	68.8	52.8	61.6	80.0	35.0	67.8	49.8	58.4
June	88.0	47.0	78.2	61.5	70.4	81.5	35.0	70.8	52.1	61.1
July	92.5	48.0	80.2	62.5	71.7	93.0	43.0	82.6	63.3	72.2
August	95.0	56.0	84.6	67.0	75.7	86.0	48.5	78.4	58.8	67.4
September	84.0	44.0	73.6	55.6	64.2	86.0	41.0	73.9	52.8	62.4
Annual	95.0	27.0	66.3	50.8	58.5	93.0	28.0	64.3	47.1	54.7

SAN DIMAS EXPERIMENTAL FOREST
Air Temperature, °F.

Fern Small Watershed No. 1 Climatic Station, Elevation 5,200 feet

	Absolute		Mean			Absolute		Mean		
Month	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean
			1941-42					1942-43		
October	81.0	31.0	61.3	45.3	51.1	83.0	32.0	67.9	51.7	58.1
November	78.0	31.0	63.8	47.4	53.6	78.0	31.0	63.2	46.3	53.5
December	71.0	24.0	51.1	35.4	41.4	72.0	33.0	57.7	41.7	48.6
January	71.0	20.5	54.8	40.2	45.4	75.0	26.0	52.5	38.1	44.3
February	63.0	22.5	49.6	33.0	39.0	74.0	22.0	55.4	38.7	46.2
March	72.0	22.5	55.5	38.1	44.8	69.0	33.0	53.8	38.9	45.6
April	67.0	28.0	54.2	37.6	44.4	77.0	24.5	61.1	44.2	52.2
May	86.0	31.5	64.2	45.2	53.3	85.0	36.0	70.5	51.1	59.6
June	89.0	46.0	77.3	57.1	66.0	85.0	34.5	69.9	51.8	59.9
July	95.5	56.0	88.2	69.5	77.1	96.0	52.0	83.6	63.7	73.1
August	95.0	42.5	84.2	64.5	72.5	89.0	55.0	81.5	62.9	71.2
September	87.0	44.0	79.5	59.8	67.3	93.0	52.0	81.8	62.8	70.9
Annual	95.5	20.5	65.4	47.8	54.8	96.0	22.0	66.6	49.4	57.0
			1943-44					7-year period, 1937-44		
October	87.5	32.0	69.3	51.3	58.5	87.5	31.0	67.7	50.2	57.3
November	74.0	31.0	63.4	47.2	53.6	78.0	27.0	62.5	45.6	52.9
December	63.5	26.0	49.1	35.5	41.6	73.0	24.0	55.3	40.3	47.0
January	71.5	25.0	51.2	37.2	43.0	75.0	20.5	52.4	38.0	44.3
February	66.0	25.0	44.5	30.5	36.8	74.0	15.0	49.1	34.2	41.0
March	68.5	22.0	53.2	37.8	44.7	73.0	22.0	54.1	38.1	45.3
April	73.5	28.0	55.0	37.4	45.6	77.0	24.5	58.1	41.1	49.2
May	76.0	29.5	65.2	46.5	55.2	86.0	29.5	67.2	48.6	57.4
June	91.0	32.0	65.7	47.5	56.3	91.0	32.0	73.0	54.3	63.2
July	86.5	51.0	79.1	61.0	69.2	96.0	43.0	82.7	64.0	72.6
August	98.0	57.0	83.8	64.3	73.0	98.0	42.5	82.8	64.0	72.3
September	92.0	41.5	81.1	60.2	69.6	93.0	41.0	77.6	58.6	67.7
Annual	98.0	22.0	63.5	46.4	53.8	98.0	15.0	65.3	48.2	55.8

SAN DIMAS EXPERIMENTAL FOREST
Air Temperature, °F.

Monroe Canyon Climatic Station, Elevation 1,700 feet

	Absolute		Mean			Absolute		Mean		
Month	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean
			1942-43					1943-44		
October	93.5	37.0	78.7	45.1	56.6	97.0	35.0	76.7	47.0	58.0
November	88.5	31.5	72.5	39.9	49.4	83.0	34.0	73.0	40.8	51.7
December	82.0	30.5	65.9	36.0	44.7	74.0	30.5	58.2	37.3	45.4
January	81.0	26.0	62.6	37.6	45.4	80.0	28.0	60.2	34.9	44.5
February	83.5	28.0	66.4	38.6	48.0	72.5	27.5	55.0	33.6	42.7
March	74.0	34.0	62.8	41.9	49.4	78.5	28.0	63.8	37.8	49.0
April	86.0	32.5	68.7	43.1	52.4	77.0	30.5	64.5	37.2	49.4
May	88.0	35.0	76.6	46.4	57.9	88.5	37.0	68.9	43.4	54.8
June	93.0	36.5	79.5	45.1	58.9	88.5	37.5	72.2	45.3	56.7
July	104.0	44.0	86.0	49.8	65.2	94.5	39.5	81.0	46.0	60.6
August	93.5	44.0	86.5	51.7	66.0	103.0	43.0	88.4	51.1	66.4
September	105.5	45.5	89.2	52.6	66.5	103.0	42.5	80.7	51.7	63.2
Annual	105.5	26.0	74.7	44.0	55.2	103.0	27.5	70.3	42.2	53.6

SAN DIMAS EXPERIMENTAL FOREST
Air Temperature Summary

10-year period, 1933-34 to 1942-43

Month	San Dimas Canyon	Tanbark Flat	San Gabriel Divide	Fern Canyon	Year	San Dimas Canyon	Tanbark Flat	San Gabriel Divide	Fern Canyon
	Mean Maximum, °F.					Mean minimum, °F.			
October	78.6	73.0	73.4	68.6		49.9	49.0	53.6	49.3
November	73.6	67.4	67.1	63.0		45.4	43.4	49.3	44.2
December	65.7	61.9	59.6	56.4		42.2	40.6	43.4	39.8
January	62.5	58.4	55.9	52.6		39.6	38.2	39.9	36.1
February	62.3	57.4	54.9	51.9		40.2	37.6	38.2	35.2
March	66.4	61.5	60.7	57.3		41.4	39.8	41.5	38.7
April	71.8	65.7	65.4	62.3		45.1	42.2	43.6	42.1
May	78.0	71.5	72.6	70.1		48.7	46.0	50.2	48.6
June	83.4	77.6	79.8	77.3		50.6	49.8	56.5	55.4
July	92.9	86.2	89.1	86.2		56.0	57.9	65.4	63.2
August	92.6	86.4	89.4	86.3		57.2	58.9	65.6	63.5
September	90.3	83.0	84.7	81.2		55.7	56.1	60.8	58.1
Annual	76.6	70.9	71.1	67.8		47.8	46.7	50.8	48.0
	Mean Mean, °F					Annual mean, °F.			
October	62.8	60.2	57.1	57.7	1933-34	59.4	60.9	63.3	60.6
November	57.7	54.5	58.2	52.4	1934-35	59.6	56.8	59.0	56.9
December	53.1	50.2	46.5	47.4	1935-36	61.1	57.7	62.1	59.3
January	50.4	47.4	49.8	43.5	1936-37	60.5	57.9	60.1	56.5
February	51.0	47.0	44.2	42.9	1937-38	61.9	58.7	57.6	58.0
March	53.4	50.2	49.2	47.2	1938-39	61.5	57.8	57.6	56.3
April	57.5	53.4	48.9	51.6	1939-40	62.5	59.4	61.2	57.9
May	62.3	58.4	57.6	59.0	1940-41	60.5	58.1	57.3	55.5
June	65.7	63.4	67.2	66.0	1941-42	60.2	56.3	58.7	53.8
July	72.8	71.8	79.4	73.9	1942-43	61.6	58.1	60.7	56.2
August	72.9	72.8	75.9	73.9					
September	70.5	68.7	71.4	68.6					
Annual	60.9	58.2	58.9	57.1					

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PAPER . . . No. 37
JULY 1959

FOUR HUNDRED SIXTY STORMS

DATA FROM THE SAN DIMAS EXPERIMENTAL FOREST

BY LYLE F. REIMANN
EVERETT L. HAMILTON

PACIFIC SOUTHWEST
FOREST AND RANGE
EXPERIMENT STATION
BERKELEY . . . . CALIFORNIA

FOREST SERVICE — U.S. DEPARTMENT OF AGRICULTURE

Studies reported here were
conducted in cooperation with

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF FORESTRY

FOUR HUNDRED SIXTY STORMS

Twenty-five Years of Rainfall Data from the San Dimas Experimental Forest

By Lyle F. Reimann
and
Everett L. Hamilton

Miscellaneous Paper No. 37 July 1959

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION

FOUR HUNDRED SIXTY STORMS

Twenty-five Years of Rainfall Data from the San Dimas Experimental Forest

Lyle F. Reimann
and
Everett L. Hamilton[1]

This report presents data from the master recording rain gage at Tanbark Flat field headquarters of the San Dimas Experimental Forest in southern California.

Rainfall quantities by days, maximum rainfall rates by storms, and attendant storm data are given for the 25-year period 1933 to 1958. These data, as a long term and complete series, should be useful to workers in the fields of water supply and control, plant growth, and climate.

The San Dimas Experimental Forest was established in 1933 as a field laboratory for research in brushland watershed management. It is located 30 miles northeast of Los Angeles, in the San Gabriel Mountains. Research objectives are, first, to determine how watersheds function, what happens to the precipitation, and how water and soil movement are influenced by conditions of vegetation, soil, climate, geology, and topography; second, to develop methods of watershed management that will insure the maximum yield of useable water at a minimum of sedimentation and flood hazard. Fundamental to these objectives, a rainfall sampling network was established and supplementary studies were carried on to learn about rainfall behavior in mountain watersheds and develop better methods of rainfall measurement. The studies have been reported in U. S. Department of Agriculture Technical Bulletin 1096.

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[1] Lowell A. Andrews and E. B. Goodwin provided major assistance in collection of the data reported here.

The main San Dimas Experimental Forest rain gage, designated IF-35 (fig. 1) is located in the Tanbark Flat field headquarters of the San Dimas Experimental Forest at 2725 feet elevation (latitude 34°12', longitude 117°46'). It is set on a small bench having a south to southwesterly exposure (fig. 2). The site is screened by Coulter pines so the gage is well protected from wind and well exposed to rainfall. It was established originally by Los Angeles County Flood Control District in 1928, and has been observed since 1933 by the experiment station staff. The gage has had good maintenance, and tests have indicated that it sampled local rainfall accurately[2]. In fact, its yearly average is very close to the yearly average rainfall for the whole experimental forest. The gage is in the U. S. Weather Bureau hydrometeorological net, and hourly readings are published monthly in California Climatological data as "San Dimas Tanbark Flat", index number 7750. Los Angeles County Flood Control District publishes monthly amounts as "Tanbark Flat" number 158 in their Biennial Report.

Gage IF-35 is a weighing-recording Fergusson type with a capacity of 12 inches. It is operated with a 24-hour chart which is changed daily at 1700 hours. When the chart is changed, the gage catch is measured volumetrically, and the recording pen is reset to zero. The rainfall record is tabulated by dividing the pen trace into sections of uniform slope, then recording for each section the quantity of rainfall and its duration in minutes on Form USDA-4 recommended by the National Research Council for federal interagency use. Therefore, rainfall amounts are available for any time interval within the capability of the gage, and rain rates can easily be computed. Rates for time intervals of 2 minutes to 24 hours are entered for each storm tabulation. The precipitation record is presented here in three sections.

Section 1 presents daily rainfall amounts, midnight to midnight, and annual summaries for the hydrologic year starting October 1. Annual rainfall is shown by figure 3.

Section 2 presents the annual summaries of maximum storm rates for storms greater than ½-inch in amount.

Section 3 presents pertinent storm data by hydrologic years according to the following definitions:

Rainfall.--The amount of water falling from clouds during a storm--synonymous with "precipitation".

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[2] Rainfall-measurement as influenced by storm-characteristics in southern California mountains, E. L. Hamilton. Amer. Geophys. Union Trans. Pt. III: 502-518.

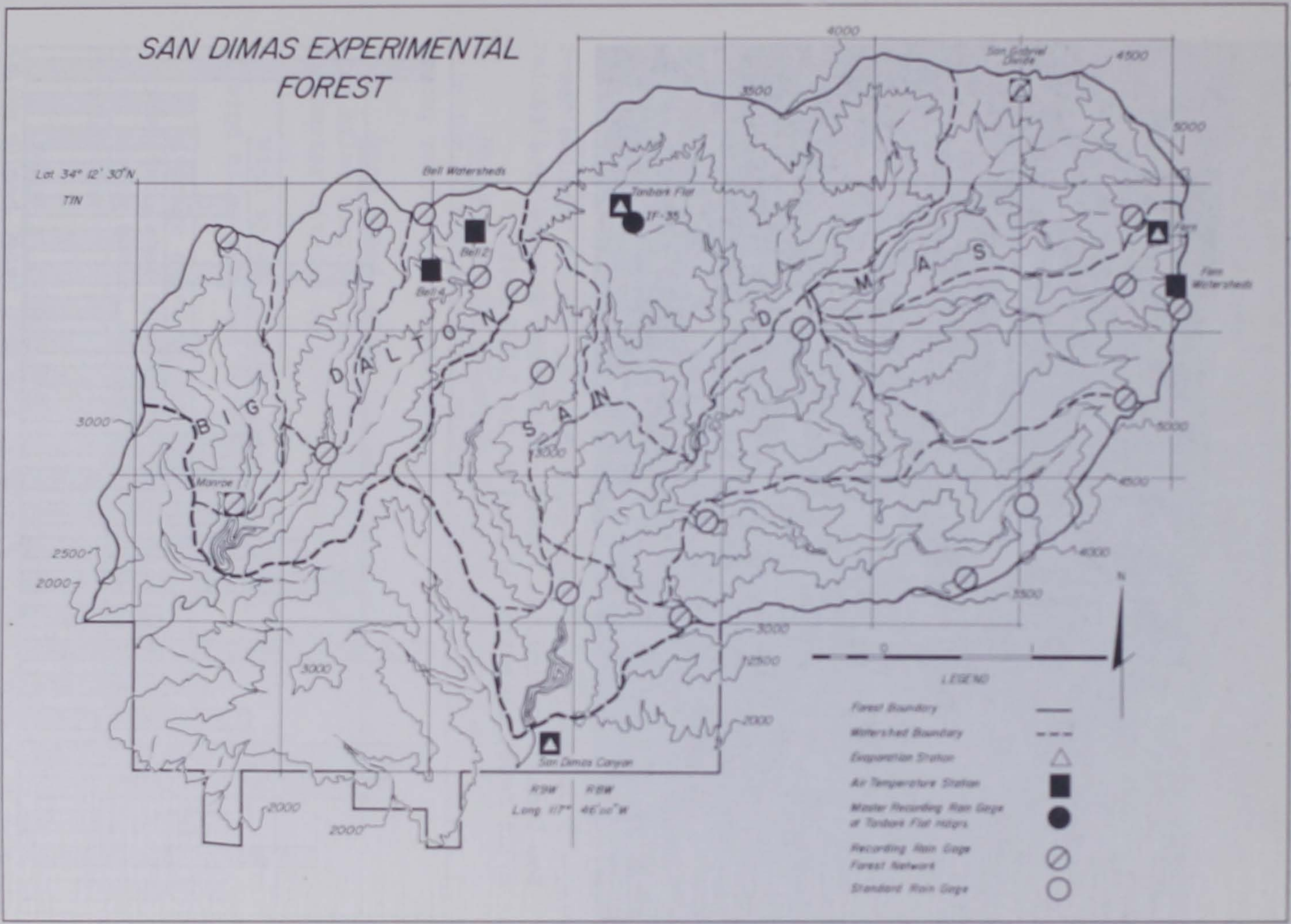
SAN DIMAS EXPERIMENTAL FOREST
Lat 34° 12' 30"N
T1N
Bell Watersheds
Bell 2
Bell 4
Tanbark Flat
TF-35
San Gabriel Divide
Fern
Fern Watersheds
Monroe
San Dimas Canyon
BIG DALTON
SAN DIMAS
3000
3500
4000
4500
5000
2500
2000
R9W
R8W
Long 117° 46'00"W
N
0
1
LEGEND
Forest Boundary
Watershed Boundary
Evaporation Station
Air Temperature Station
Master Recording Rain Gage at Tanbark Flat Hdqrs.
Recording Rain Gage Forest Network
Standard Rain Gage

Figure 1.--San Dimas Experimental Forest in the San Gabriel mountains of southern California showing climatic stations and present rain gage locations.

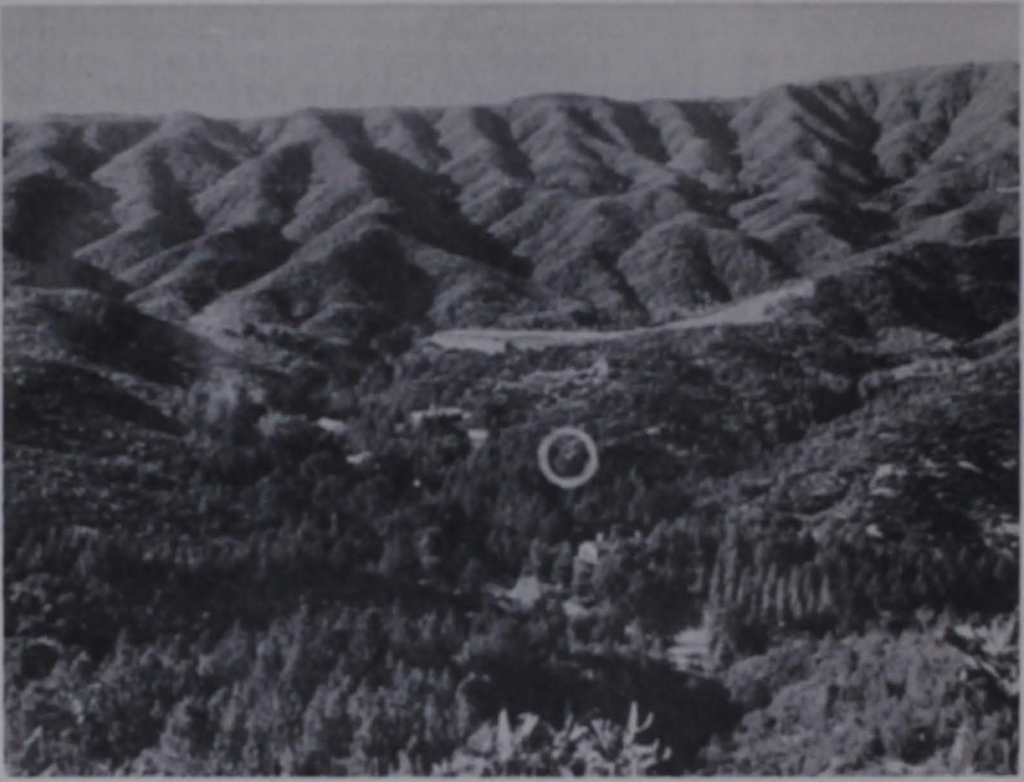

Figure 2.--Situation of rain gage IF-35 at Tanbark Flat on the San Dimas Experimental Forest. Elevation at gage site is 2,725 feet, elevation of skyline is 3,500 feet.

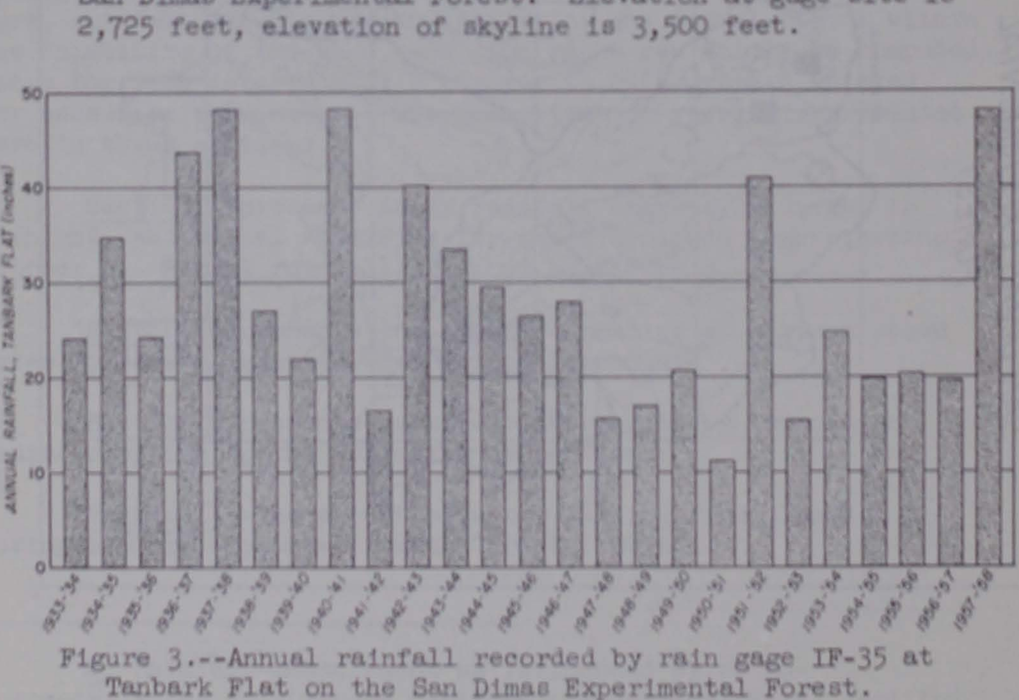

Figure 3.--Annual rainfall recorded by rain gage IF-35 at Tanbark Flat on the San Dimas Experimental Forest.

Storm.--A meteorological disturbance producing at least 0.10 inch of precipitation in the master rain gage number IF-35 at Tanbark Flat field headquarters. A period of 24 hours without rainfall and with clearing conditions marks the end of a storm. A new storm, however, may be designated within 24 hours of the cessation of rainfall if attendant meteorological conditions warrant it.

Storm number, Column 1.--A serial number given a storm rainfall defined above. Rainfalls less than 0.10 inch are designated a, b, c, etc., with the preceding storm number. The storm number series started with the establishment of the San Dimas Experimental Forest in 1933.

Storm duration, Column 6.--The total number of hours and minutes elapsed time from start to finish of a storm.

Actual raining time, Column 7.--Storm duration minus all intervals of 2 hours or more without rainfall.

Storm break, Column 8.--Cessation of rainfall within a storm for 2 or more hours.

Days since last rain, Column 9.--Number of days between stop and start of measurable precipitation, including trace.

Storm total, Column 10.--Total rainfall measured in recording gage IF-35. "T" (trace) less than 0.01 inch of rainfall within a storm period.

Maximum hourly rainfall rate, Column 11.--The greatest rise for 60 consecutive minutes in the recording rain gage trace, recorded as inches per hour.

Wind speed, storm average, Column 12.--Total number of wind miles recorded for duration of a storm by Tanbark Flat anemometer divided by hours of storm duration.

Wind speed, maximum hourly, Column 13.--Greatest number of wind miles recorded in one hour.

Average storm temperature, Column 14.--Total number of degrees tabulated from Tanbark Flat thermograph by 2-hour intervals, during actual raining time, times 2, divided by hours of raining time.

Range in precipitation, Column 15.--Total storm rainfall at San Dimas Guard Station (elevation 1,500 feet), the lowest gage location on the San Dimas Experimental Forest, and in Fern Small watershed number 2 (elevation 5,200 feet), the highest gage location.

SECTION I

DAILY RAINFALL AMOUNTS AND ANNUAL SUMMARIES

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1933-34

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1				4.63				0.05				
2												
3			0.02									
4					T							
5									0.56			
6												
7												
8												
9												
10												
11												
12			1.15									
13			4.05						.03			
14			.62				0.10		.04			
15			.31		0.07		.11					
16												
17												
18												
19					.57						0.10	
20					.15							
21												
22					.82							0.03
23				T	1.38	0.10	.01					.20
24				.45	.94							
25												
26												
27												
28		0.65										
29		.06										
30	0.14	.13	.96									
31	.42		5.66									
Total	.56	.84	12.77	5.08	3.93	.10	.22	.05	.63	0	.10	.23

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1934-35

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1		0.05								0.03		
2						1.05						
3												
4				0.72	1.27	.49	0.12					
5				1.49	1.33	.05						
6	0.10				.15							
7			0.18		.05	.67	.40					
8			.44	.10	.30	.15	3.70					
9				.86	.04	.18						
10				.08								
11												
12			.79									
13			2.42									
14			1.93	.12	.10							
15		.32		1.53								
16	.02	1.33						0.07				
17	4.86	.70										
18	1.61	T		.94								
19		.30		.18		.06						
20												
21						.41						
22						.07						
23						.60						
24						.22						
25											0.09	
26											.02	
27			.10									
28			.91					.02				
29							.95					
30							.12					
31	.01											
Total	6.60	2.70	6.77	6.02	3.24	3.95	5.29	.09	0	.03	.11	0

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1935-36

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1	0.05				1.87							
2	.11	0.11			2.49							
3			0.07				1.41					
4			.17				1.14					
5												
6												
7										T		
8												
9										T		
10										T		
11				0.04	4.10							
12					1.53							
13					1.33							
14	.27				1.34							
15					.40							
16					1.33							
17		.30			.12							
18		.07			.57							
19												T
20												
21						0.19						
22		.01			.68	.08						
23					1.04							
24					.05	.59						
25												
26												
27												
28				.05								
29			.92	.03								
30						1.49						
31				.04		.29						
Total	.43	.49	1.16	.16	16.85	2.64	2.55	0	0	T	0	T

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1936-37

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1							0.02					
2							.38					
3			0.05									
4			.18						T			
5				0.99	0.50				0.06			
6				.61	3.69				T			
7				.16	.41							
8				.06								
9												
10												
11					.04							
12				.68		3.01						
13					2.43	1.77						
14			.95		1.93							
15			2.97		.09	1.16						
16	0.47		.15			.27						
17	.42					.24						
18	.41					.08						
19				.03								
20												
21		T				.03						
22		0.06				1.39						
23		.11										
24					.62	.54		0.03				
25			.85		.66			.09				
26			.07				.24	.45				
27			3.93			.38						
28			.71	.25				.03				
29	.18		.01	.74				.11				
30	.30		4.11	1.91				.10				
31	1.24		.53	.05				.01				
Total	3.02	.17	14.51	5.48	10.37	8.87	.64	.82	.06	0	0	0

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1937-38

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1					1.60	0.62		0.07				
2					.02	11.56		.17				
3					3.32	1.19						
4					.40							
5												
6												
7		0.04				.03						
8					.20	.80						
9			0.19		1.47				0.05			
10			.58		.09				.16			
11			2.37		1.96	.46			.01			
12					.46	2.50	0.24					
13						1.05	.01			T		
14				0.10	.04							
15				2.52				.04				
16								.14				
17								.02				0.06
18				.26	.65							
19				.27	.07							
20												
21												
22			.10									
23			1.43									
24							.68					
25							.32					
26			.80									
27					1.55							
28				.11	6.28	.10					T	
29				.20			.51				T	
30							.16					
31				.10								
Total	0	.04	5.47	3.56	18.11	18.31	1.92	.44	.22	T	T	.06

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1938-39

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1	0.02				0.11		0.29					
2				0.01			.56					
3					1.12							
4												
5				2.35								
6												
7					.04							
8					.89							
9						1.36						
10		0.05			.06	.21						0.10
11												.16
12												.04
13							.11	0.13				
14			0.59				.03	.03				
15	.36		1.09					.02				
16			.09									
17			.38									
18			3.38									
19			1.69		.04	.05						
20			1.81			.27						
21			.01	.93								.13
22						.01						
23						.01	.05					
24												2.15
25						.02						2.96
26						.86						.14
27				.03		1.46						
28				.03		.04						
29												
30				.60								
31				.05								
Total	.38	.05	9.04	4.00	2.26	4.29	1.04	.18	0	0	0	5.68

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1939-40

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1					1.52		0.09					
2	0.09				.84							
3	.01				.78							
4				0.54	.01		.02					
5			0.09									
6	.23			.14								
7	.20			2.88								
8	.02	0.30		1.57								
9		.02		.57						T		
10				.10		T						
11			.04	.30								
12				.05	.02							
13												
14					.40							
15							.37					
16												
17												
18								0.11				
19						T						
20												
21												
22					.24							
23			.92	.87	.02							
24	.04											
25					2.46	0.02	.10					
26					.05	.07	2.11					T
27						.17						
28					.34							
29					.85							
30												
31				.44		1.98						
Total	.59	.32	1.05	7.46	7.53	2.24	2.69	.11	0	T	0	T

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1940-41

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1						1.02	0.42					
2						.48	.32	0.07	T			
3						.83		.08				
4				0.05		2.41	1.71					
5						.02					T	
6					0.82				0.08			
7				T					.02			
8	0.06								T			
9							.95					
10				.58			.55				T	
11			0.20		1.54	.09	.69					
12			.12			1.74	.41					
13						1.18	T					
14				.08	.89	.95	.07					
15					.68						0.03	
16			1.78		.34							
17		1.14	1.14		.55		.15					
18		.73	.31					.02				
19					2.02							
20					1.99							
21				.55	1.47							
22				.14	.35							
23			1.94	.17	.06							
24			2.22	1.36	.67							
25	2.06			.03						T		
26	.41			.23						T		
27								T				
28			.13		2.26	1.03						
29			.33			.80	.04					
30			.52				.74					
31						1.41						
Total	2.53	1.87	8.69	3.19	13.64	11.96	6.05	.17	.10	T	.03	0

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1941-42

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1				0.07								
2												
3			0.62				0.65					
4							.37					
5							T					
6							.07					
7												
8												
9			.21				.06				0.19	
10			1.80				.73	T			.36	
11		0.09				0.48	.15					
12	0.14	.28				.04						
13						.07						
14						1.24	.35					
15						.04						
16		.03										
17		.03					.23					
18												
19	.21											
20	.21											
21	.29				1.27		.26					
22	.20			.11	.29		.12					
23	.40		.88							0.02		
24	.02											
25			.55				.01					
26			.10				.01					
27	.27				.06							
28			1.15				.21					
29		.20	.96				.01					
30			.50									
31			.04									
Total	1.74	.63	6.81	.18	1.62	1.87	3.23	T	0	.02	.55	0

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1942-43

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1									0.11			
2									.04			
3						3.15			.01			
4			T			3.69						
5			T			.10	0.66					
6						T	.88					
7							.11					
8					0.65		.67					
9						.03	.01					
10						.02						
11	0.40						.16		.02			
12	.51						.03		.02			
13							.02					
14												
15							.13					
16							.04					
17						.48						
18		0.09				.18						
19		.58										
20					.23							
21				1.76	1.10	.07						
22				14.32	3.88	.11						
23			0.06	4.82	.41							
24			1.09		.83							
25			.30	.03								
26				1.32								
27				.16								
28	.93											
29				.07								
30				.86								
31				.09								
Total	1.84	.67	1.45	23.43	7.10	7.83	2.71	0	.20	0	0	0

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1943-44

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1						1.46			0.09			
2				0.05		.52			.13			
3				.02	1.18	.08						
4				.01	.06	.22						
5			0.26	.25								
6			.06	.12								
7												
8					.91		0.27		.05			
9									.09			
10			3.42									
11			1.62			T						
12			.05			.13						
13						.60						
14					.22							
15					.25							
16												
17		0.29	.01		.18							
18	1.26		.63									
19		.01	1.47		.44							
20			1.33		2.30							
21		.02	.07		3.03							
22					5.25							
23				.80	.18							
24				.05	.09							
25					.03							
26				.08	.42		.03					
27	.03			.08			1.32					
28			.21				.14					
29	.03		.38		.32							
30			.57	.08				0.01				0.01
31				.19								
Total	1.32	.32	10.08	1.73	14.86	3.01	1.76	.01	.36	0	0	.01

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1944-45

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1					2.14	0.18	0.03				0.15	
2			0.32		3.47	.24	.03					0.09
3					.02	.51						
4		0.31				.41						
5		.95				.38			0.03			
6		.02							.01			
7		T						T				
8							.44	0.03				
9							.06	.01				
10		2.68										
11		5.45										
12		.21						T				
13		.71				.03		.02				
14		.68				.11						
15					.06	2.32						
16						.09						
17					.02	.42					.04	
18					.19						.53	
19				0.64	.32							
20					T							
21						.86			T			
22			.02			.55						
23	T					.17						
24					.08							
25						.19	.01					
26						.61	.02					
27	T		.02		.50							
28			.85		.36							
29			.50									
30												
31				.55				.01				
Total	T	11.01	1.71	1.19	7.16	7.07	.59	.07	.04	0	.72	.09

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1945-46

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1							0.05					
2				0.06			.46					
3				.35	2.15							
4			0.02	T								
5		0.01		.06								
6	0.56	.48					.06					
7	.04											
8	.11											
9								0.02				
10								.17				
11			.35		.01							
12												
13						0.65						
14												
15		.01			.23							
16		.01										
17												
18						T				T		
19						.64				0.03		
20						.33		.02				
21			4.92			.04		.03				
22			5.40									
23			2.62									
24			.03									
25			.03									
26								.10				
27												
28						.50						
29	.28	.01				.49						0.34
30	.23					4.88						.12
31						.07						
Total	1.22	.52	13.37	.47	2.39	7.60	.57	.34	0	.03	0	.46

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1946-47

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1	1.50											
2												
3	.60					0.36	0.02					
4	.02					T						
5			T			.09						
6			0.48									
7		0.02										
8		.03									0.05	
9					0.48							
10		.04						0.03				
11		.87										
12		1.93		0.01								
13		2.33						.01				
14		.81						.12				
15								.03				
16	.32				.02							0.27
17					1.02							
18					.03	.08						
19		.08				.01			T			
20		4.32				.45	.02		0.06			
21						.22	.12					
22						.02	.15					
23		1.74	.17			.01						
24			.25									
25			2.46									
26	T		1.46					.06				
27	.81		1.06		.01	.36		.07				
28	.17			1.47		.37						
29								T				
30								.07				
31												
Total	3.42	12.17	5.88	1.48	1.56	1.97	.31	.39	.06	0	.05	.27

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1947-48

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1		T	0.15		0.08				0.67			
2			.01		.08		0.33		.05			
3							1.24					
4			2.10		.18							
5			.80		2.78		.30					
6					.66		.05					
7												
8						T						
9		0.08				0.01						
10							.15					
11												
12												
13						.92						
14						1.06						
15		T										
16						.02						
17						.65						
18								0.05				
19						.33						
20			.04			.01						
21												
22												
23												
24						.96						
25				0.01		.02						
26				.03								
27								.01				
28					.24		1.65	.01				
29						.03						
30								.06				
31								.01				
Total	0	.08	3.10	.04	4.02	4.01	3.72	.14	.72	0	0	0

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1948-49

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1							0.01					
2						0.07	.01					
3		T	0.54		0.31	.01						
4						.71						
5												
6												
7					.44	.11						
8				0.02								
9				.37								
10				.14		.29						
11				.37	.65	.37						
12				.08								
13				.25				0.08				
14				.17			T	.24				
15							.02	.30				
16			.36					.13				
17	0.10		1.42				.02	.22				
18	.33						.02	.42				
19				1.03		.35	.01	.40				
20				1.23		.01						
21				.02								
22			.40	.84		.17						
23			T	.14		.01						
24				.01	.90	.09						
25					.03							
26			.91		.96							
27			.33		.22							
28					.01	.04						
29	.02											
30	.09					.11						
31						.03						
Total	.54	T	3.96	4.67	3.52	2.37	.09	1.79	0	0	0	0

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1949-50

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1								T				
2				0.15		T		T				
3								0.07				T
4												T
5					0.30							T
6					2.26				0.08			0.04
7	0.01		0.03									
8		0.05	.46	1.56			1.59					
9		1.05	.01				.28			T		
10		2.82	.04		.48							
11				.96	.02							
12				.15								
13												
14				.10								
15	.05											
16	.04							T				
17	.08		.13					.12				
18	T		4.52									
19	T		.77									
20												
21												
22							.04					
23							.01	.02				
24						1.65	.01		T	T		
25						.09						
26												
27							.02					
28				.39			.08					
29				.25								
30												
31												
Total	.18	3.92	5.96	3.56	3.06	1.74	2.03	.21	.08	T	0	.04

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1950-51

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1						0.84						
2												
3							0.09					
4				0.02			.43					
5							.27		T			
6							.07					
7												
8									T			
9												
10				.34								
11				1.20	0.07			T				
12					.07							
13		1.19						0.09				
14		.06						.05				
15		T					T					
16				.17			T					
17												
18		.05		.17			.01					
19		.27		.47			.01					
20							.01					
21							.02					
22					.02							
23					.24							
24					.01							
25					T		1.00					
26	0.14				.75							
27	.12			T	.09	T						
28				.13			1.44			T		0.03
29				1.30		.01	.14				T	
30				.03		.03						
31	.02											
Total	.28	1.57	0	3.83	1.25	.88	3.49	.14	T	T	T	.03

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1951-52

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1			0.46			0.80						
2			.04									
3			.01									
4			.78									
5			1.44									
6				0.09		.14						
7				.45		3.03	0.96					
8				.02		.05	.02					
9					T							
10						1.01	.35					
11			.74		0.02	.01	.01					
12			1.08	2.84		.37						
13				.59		.15						
14						.10						
15				2.27		2.80						
16				2.64		.39						
17				1.63	.09							
18				1.00								
19		1.38	.58				.27					0.36
20		1.18					.01					.10
21		.04										
22		.01										
23		.12			T							
24	0.53			.16	T							
25	1.27			.70			.74					.05
26							.01		0.03			.03
27							.16			0.03		
28			.15				.10				0.02	
29	T		3.71		.76		.15					
30	.01		2.06									
31												
Total	1.81	2.73	11.05	12.39	.87	8.85	2.78	0	.03	.03	.02	.54

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1952-53

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1			1.71			0.43			T			
2												
3												
4												
5			.02				0.03					
6			.08	0.86			.06		T			
7		0.20		.31					T			
8		.45		.02								
9												
10												
11											0.07	
12										T		
13				.43								
14		.92										
15		1.91						0.03				
16		.01										
17			.02									
18									0.07			
19			.04			.80	.03		.01			
20			1.12			.56	.40					
21							.33					
22		.29										
23					0.64							
24												
25												
26												
27			.02				.91	.02				
28			.64		.24	.10	.02	.14				
29		.37					.01					
30		.35	.78				.01					
31			.01									
Total	0	4.50	4.44	1.62	.88	1.89	1.80	.19	.08	T	.07	0

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1953-54

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1												T
2		T										
3											T	
4		0.02	0.41									
5		.18										
6												
7												
8						T						
9								T				
10						T						
11				0.04								
12				.74						T		
13					3.47					T		
14		1.05			.77							
15												
16						1.18		T	T			
17				.07	.07	.12			T			
18	T			1.44	.02							
19				4.96		.07						
20		.07		.09		1.44						
21						.56						
22	0.19					.50						
23				.06		.28						
24				3.47		.73						
25				1.23		.07			T	T		
26									T			
27							0.13		T			
28							.08					
29						.89	T	T				T
30						.51	.01					
31												
Total	.19	1.32	.41	12.10	4.33	6.35	.22	T	T	T	T	T

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1954-55

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1				1.12			T	0.53				
2				.02								
3			1.32	.03						T		
4			.03								0.03	
5												
6				.60								
7								.65				
8								.07				
9			.61	.04								
10		0.34	.01	1.87		0.66						
11		2.31				.32					T	
12		.03										
13									0.03			
14						T		T	.02			
15		.18	T	.12								
16		.02		1.15	0.31	T						
17					.43							
18				1.90			T					
19				.05						T		
20												
21							0.24					
22							.37					
23												
24								.06				T
25					.02			.02	T			
26					.21		.12		T			
27					1.27							
28												
29		.20							T			
30				.23			2.21	.14				
31				.02				.03			T	
Total	0	3.08	1.97	7.15	2.24	.98	2.94	1.50	.05	T	.03	T

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1955-56

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1			0.33				0.19					
2			.04				T			T		
3												
4			.40									
5						0.01						
6			.02			.01						T
7												
8								0.25				
9								1.04				
10							.02	.01				
11				T			.03					
12		T					2.11					
13		0.09					.15					
14		.95										
15												
16					0.10							
17		.11					T	T				
18							T					
19												
20				0.01								
21	0.01	.80										
22				.05	.08							
23			.13	.05	1.31							
24			.02		.03		T	T				
25			.01	2.23				T		T		
26			.08	6.97			1.05	T		T		
27			.01	.81			.07	.07			T	
28				.01				.02			T	
29				.01				T				
30				.32			T	T				
31			T	.11		.06						
Total	.01	1.95	1.04	10.57	1.52	.08	3.62	1.39	0	T	T	T

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1956-57

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1						0.08						
2						.01				0.02		
3												
4	0.27		T	0.25								
5			0.95	1.05								
6			.10									
7				.38	T			0.03				
8				.02	0.03				T			
9				.25	T	.89			0.19			
10				.65	T	.01		.65	.19			
11					T			.48				
12				1.90		T						
13				1.80								
14								.04				
15												
16					T	.64						
17					T	T	0.75					
18					.01		.15	.59				
19					T	.01		.87				
20				.36	T		.85	.11				
21				.01		T	.14	.02				
22					.01			T				
23				.10	1.77		.01	.03				
24				.28				T				
25				.30								
26				.64								
27				.46								
28	.06			.08	.99							
29				.33								
30												
31												
Total	.33	0	1.05	8.86	2.81	1.64	1.90	2.82	.38	.02	0	0

DAILY RAINFALL
Tanbark Flat
Hydrologic year 1957-58

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1						T	4.37	T				
2		1.26			0.31		.19	T				
3		.21			2.47		3.39					
4		.08	0.65		3.24		.10					
5		.08	1.33		.03							
6						1.26	.98					
7						.16	1.29					
8					.02			T				
9												
10				0.04		.42						
11	1.58					.22		0.11				
12					.04	.28		.01				
13	.37					.04					0.02	
14	.34					.01						
15			3.61			1.64					.49	
16		.02	2.19			1.33			0.02			
17			.80			.19						
18					T							
19	.01				2.21							
20	1.03					.80						
21	.04					.43						
22						.48						
23												0.28
24				.10								
25				1.53	1.50							
26	.10			2.14								
27				T		1.08						
28	T				.38							
29	T											
30	.22			.01		.05	T					
31	.37					.13						
Total	4.06	1.65	8.58	3.82	10.20	8.52	10.32	.12	.02	0	.51	.28

SUMMARY OF MONTHLY RAINFALL
Tanbark Flat

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1933-34	0.56	0.84	12.77	5.08	3.93	0.10	0.22	0.05	0.63	0	0.10	0.23	24.51
1934-35	6.60	2.70	6.77	6.02	3.24	3.95	5.29	.09	0	.03	.11	0	34.80
1935-36	.43	.49	1.16	.16	16.85	2.64	2.55	0	0	T	0	T	24.28
1936-37	3.02	.17	14.51	5.48	10.37	8.87	.64	.82	.06	0	0	0	43.94
1937-38	0	.04	5.47	3.56	18.11	18.31	1.92	.44	.22	T	T	.06	48.13
1938-39	.38	.05	9.04	4.00	2.26	4.29	1.04	.18	0	0	0	5.68	26.92
1939-40	.59	.32	1.05	7.46	7.53	2.24	2.69	.11	0	T	0	T	21.99
1940-41	2.53	1.87	8.69	3.19	13.64	11.96	6.05	.17	.10	T	.03	0	48.23
1941-42	1.74	.63	6.81	.18	1.62	1.87	3.23	T	0	.02	.55	0	16.65
1942-43	1.84	.67	1.45	23.43	7.10	7.83	2.71	0	.20	0	0	0	45.23
1943-44	1.32	.32	10.08	1.73	14.86	3.01	1.76	.01	.36	0	0	.01	33.46
1944-45	T	11.01	1.71	1.19	7.16	7.07	.59	.07	.04	0	.72	.09	29.65
1945-46	1.22	.52	13.37	.47	2.39	7.60	.57	.34	0	.03	0	.46	26.97
1946-47	3.42	12.17	5.88	1.48	1.56	1.97	.31	.39	.06	0	.05	.27	27.56
1947-48	0	.08	3.10	.04	4.02	4.01	3.72	.14	.72	0	0	0	15.83
1948-49	.54	T	3.96	4.67	3.52	2.37	.09	1.79	0	0	0	0	16.94
1949-50	.18	3.92	5.96	3.56	3.06	1.74	2.03	.21	.08	T	0	.04	20.78
1950-51	.28	1.57	0	3.83	1.25	.88	3.49	.14	T	T	T	.03	11.47
1951-52	1.81	2.73	11.05	12.39	.87	8.85	2.78	0	.03	.03	.02	.54	41.10
1952-53	0	4.50	4.44	1.62	.88	1.89	1.80	.19	.08	T	.07	0	15.47
1953-54	.19	1.32	.41	12.10	4.33	6.35	.22	T	T	T	T	T	24.92
1954-55	0	3.08	1.97	7.15	2.24	.98	2.94	1.50	.05	T	.03	T	19.94
1955-56	.01	1.95	1.04	10.57	1.52	.08	3.62	1.39	0	T	T	T	20.18
1956-57	.33	0	1.05	8.86	2.81	1.64	1.90	2.82	.38	.02	0	0	19.81
1957-58	4.06	1.65	8.58	3.82	10.20	8.52	10.32	.12	.02	0	.51	.28	48.08
25-year mean	1.24	2.10	5.61	5.28	5.81	4.76	2.50	.44	.12	.01	.09	.31	28.27
Cumulative mean	1.24	3.34	8.95	14.23	20.04	24.80	27.30	27.74	27.86	27.87	27.96	28.27	

SECTION II

MAXIMUM RAINFALL RATES

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1933-34

Storm[1/]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
1	0.56											0.05	0.02	0.56
2	.65		0.55	0.55	0.46	0.35	0.26	0.20	0.12	0.11	0.08	.05	.03	.65
4	5.20		1.80	1.20	1.12	1.11	.90	.71	.55	.42	.42	.33	.21	5.12
5	.64							.24				.05	.03	.64
7	11.25							.80	.66	.52	.52	.41	.35	8.34
8	.45		1.80	1.50	1.08	.90	.80	.43	.22	.11	.08	.04	.02	.45
9	.72		.36	.36	.28	.27	.24	.15	.14	.09	.09	.06	.03	.72
10	3.14		1.44	.90	.72	.63	.56	.47	.28	.21	.16	.10	.08	2.03
13	.56			.90			.42	.21	.11			.04	.02	.56

1/ See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1934-35

Storm[1/]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
17	6.49		1.68	1.32	1.28	1.17	1.00	0.83	0.66	0.58	0.45	0.32	0.20	4.90
18	2.65		.96	.90	.68	.63	.56	.35	.21	.14	.14	.09	.07	1.60
19	.62		.36	.30	.28	.24	.20	.15	.12	.08	.06	.05	.03	.62
20	5.14		1.32	1.02	.80	.75	.72	.51	.30	.26	.22	.16	.14	3.40
21	1.01		.24	.24	.24	.24	.22	.19	.14	.14	.13	.08	.04	1.01
22	2.21		1.32	.84	.68	.66	.62	.53	.40	.25	.17	.10	.07	1.73
23	1.04		.18	.18	.16	.15	.12	.10	.08	.07	.07	.04	.04	.93
24	1.65		.96	.90	.88	.78	.68	.50	.38	.30	.24	.14	.07	1.65
25	1.12		.84	.60	.52	.52	.52	.43	.28	.19	.15	.08	.05	1.12
26	3.14		.60	.42	.40	.39	.32	.25	.18	.13	.10	.09	.08	1.90
28	1.05		3.00	1.80	1.52	1.32	1.12	.73	.36	.20	.15	.08	.04	1.05
29	.54		.60	.42	.32	.30	.28	.18	.17	.12	.08	.04	.02	.54
30	1.00		.48	.42	.28	.24	.22	.15	.14	.10	.08	.03	.03	.65
32	.82		.30	.30	.22	.22	.22	.19	.19	.16	.13	.07	.03	.82
34	4.10		1.92	1.14	.88	.86	.85	.82	.71	.60	.52	.32	.17	4.10
35	1.07		.60	.60	.44	.36	.28	.23	.20	.13	.09	.06	.03	.80

[1/] See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1935-36

Storm[1/]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
39	0.37				0.14	0.14	0.14	0.09	0.05	0.05	0.04	0.03	0.02	0.37
41	.92											.08	.04	.92
42	4.40		1.44	1.32	1.08	.90	.84	.66	.51	.40	.33	.22	.15	3.61
43	10.03		2.76	1.80	1.44	1.35	1.08	.95	.83	.49	.38	.25	.16	3.83
44	.69			.60	.32	.30	.28	.19	.12	.09	.09	.04	.02	.57
45	1.77		1.32	.96	.80	.75	.70	.63	.57	.34	.24	.13	.07	1.69
47	.59										.10	.05	.02	.59
48	1.78		.60	.60	.48	.45	.40	.35	.31	.26	.25	.15	.07	1.78
49	2.55		1.20	.98	.88	.84	.84	.68	.50	.31	.22	.14	.10	2.51

[1/] See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1936-37

Storm[1]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
50	1.30		1.08	0.60	0.44	0.39	0.36	0.27	0.14	0.11	0.08	0.05	0.04	0.91
51	1.72		.60	.48	.40	.36	.30	.30	.24	.20	.17	.08	.05	1.22
53	4.07		.60	.42	.40	.39	.36	.33	.27	.23	.20	.14	.13	3.14
54	5.57		1.44	1.08	.92	.84	.72	.66	.60	.49	.36	.22	.16	3.96
55	4.64		1.80	1.26	1.04	.99	.90	.71	.58	.54	.52	.34	.19	4.64
56	1.82		.48	.48	.40	.39	.38	.28	.23	.19	.16	.10	.07	1.60
57	.68		1.68	.90	.64	.51	.38	.25	.13	.10	.07	.05	.03	.68
58	2.95		1.08	.78	.72	.66	.56	.52	.47	.34	.28	.16	.08	1.93
59	4.60		.84	.84	.72	.69	.64	.45	.38	.32	.29	.27	.17	3.99
60	4.45		.60	.54	.52	.48	.46	.42	.37	.31	.30	.27	.17	4.04
61	1.28		.48	.30	.24	.24	.22	.21	.17	.14	.10	.07	.05	1.28
62	4.78		1.44	1.08	.76	.63	.50	.47	.38	.32	.30	.21	.16	3.87
63	1.43		2.52	1.38	1.00	.78	.54	.38	.28	.24	.17	.09	.06	1.37
65	1.42		.96	.60	.56	.54	.40	.29	.24	.20	.16	.10	.06	1.42
66	.54		.36	.24	.20	.18	.18	.16	.13	.11	.08	.04	.02	.54
70	.57		.72	.66	.52	.51	.42	.25	.14	.08	.05	.03	.02	.43

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[1] See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1937-38

Storm[1]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
72	3.14		0.82	0.65	0.51	0.48	0.47	0.39	0.33	0.32	0.23	0.19	0.10	2.34
73	1.53		.92	.63	.57	.57	.48	.41	.35	.34	.33	.12	.06	1.53
74	.80		.47	.36	.32	.30	.28	.20	.13	.09	.08	.04	.03	.80
75	2.62		3.40	3.28	2.89	2.61	2.15	1.20	.80	.50	.34	.21	.11	2.62
79	1.70		.59	.59	.44	.42	.36	.33	.31	.29	.24	.14	.07	1.70
80	3.74		.60	.60	.56	.54	.46	.34	.31	.31	.28	.23	.14	3.34
81	1.71		.92	.63	.53	.51	.36	.25	.21	.15	.11	.10	.07	1.67
82	2.47		1.08	1.08	1.08	1.08	.96	.73	.54	.37	.27	.15	.09	2.25
83	.72		.46	.29	.24	.24	.19	.17	.14	.14	.10	.06	.03	.72
84	8.27		2.73	1.90	1.70	1.38	1.29	1.20	.95	.76	.56	.30	.27	6.56
85	12.93		2.04	1.92	1.70	1.65	1.36	1.17	1.11	.95	.87	.83	.50	11.91
86	.83		.36	.30	.28	.28	.28	.18	.13	.13	.09	.06	.03	.83
87	4.01		1.45	1.30	.80	.75	.64	.45	.29	.29	.25	.21	.12	2.96
90	1.00		.87	.87	.87	.60	.43	.22	.13	.11	.09	.05	.04	.96
91	.91		.68	.63	.46	.30	.23	.12	.09	.06	.04	.04	.02	.56

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[1] See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1938-39

Storm[1/]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
95	1.77	1.26	1.01	0.82	0.70	0.67	0.56	0.43	0.37	0.23	0.17	0.10	0.06	1.32
96	7.27	1.32	1.32	.93	.84	.79	.73	.53	.35	.36	.29	.24	.15	3.50
97	2.35	1.89	1.26	1.01	.96	.94	.84	.77	.65	.42	.31	.20	.10	2.35
98	.93	.28	.28	.28	.24	.21	.16	.15	.11	.09	.07	.06	.04	.93
99	.76	.24	.24	.18	.18	.18	.16	.14	.12	.11	.10	.05	.02	.60
100	1.12												.05	1.12
101	.93	.55	.55	.55	.51	.49	.45	.32	.27	.20	.14	.08	.04	.93
102	1.57	.81	.64	.64	.56	.52	.48	.44	.35	.30	.24	.13	.07	1.57
104	2.38	.66	.66	.66	.61	.59	.55	.45	.32	.19	.14	.11	.06	1.47
105	.85	.35	.35	.34	.32	.31	.28	.22	.14	.12	.10	.07	.04	.85
108	.30	.18	.17	.14	.11	.10	.10	.09	.06	.03	.02	.02	.01	.25
110	5.25	3.60	2.19	1.17	.97	.75	.72	.48	.34	.26	.23	.21	.18	4.23

[1/] See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1939-40

Storm[1/]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
112	0.45	0.56	0.45	0.37	0.31	0.26	0.19	0.10	0.06	0.04	0.03	0.02	0.02	0.37
114	.92	.90	.80	.60	.52	.52	.52	.40	.32	.19	.14	.08	.04	.92
115	.54	.26	.26	.18	.15	.14	.13	.11	.10	.08	.07	.04	.02	.50
116	5.61	3.00	2.40	1.74	1.48	1.17	1.00	.57	.52	.49	.46	.36	.19	4.52
117	.87	.62	.53	.50	.50	.48	.48	.44	.29	.20	.14	.07	.04	.87
118	3.59	2.43	1.58	1.16	.94	.82	.69	.58	.41	.23	.20	.11	.08	1.95
121	2.51	1.18	.82	.76	.71	.65	.61	.58	.52	.39	.33	.20	.10	2.51
122	1.19	3.00	1.92	1.32	1.04	.96	.71	.37	.24	.20	.15	.09	.05	1.19
124	2.07	1.20	.84	.84	.74	.62	.45	.29	.26	.17	.14	.09	.08	1.99
126	2.21	1.17	1.17	.94	.76	.68	.63	.53	.44	.30	.22	.12	.06	1.42

1/ See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1940-41

Storm[1]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
128	2.47	1.25	1.00	0.79	0.68	0.58	0.51	0.39	0.30	0.25	0.18	0.17	0.09	2.06
129	1.87	1.16	.92	.81	.66	.55	.40	.32	.24	.18	.14	.11	.06	1.35
131	2.92	.58	.58	.50	.49	.44	.38	.33	.27	.25	.21	.15	.11	2.54
133	1.94	1.88	1.50	1.38	1.34	1.16	.86	.52	.31	.24	.20	.16	.08	1.94
134	2.22	.93	.75	.62	.53	.50	.50	.42	.36	.31	.29	.17	.09	2.22
139	1.53	.58	.58	.46	.39	.35	.31	.24	.22	.19	.17	.12	.06	1.50
142	1.54	1.20	1.20	.90	.80	.72	.62	.48	.42	.31	.22	.13	.06	1.54
143	2.46	1.23	.74	.43	.37	.34	.29	.20	.17	.16	.13	.07	.05	1.09
144	6.56	3.60	3.36	2.22	1.48	1.20	1.06	.79	.53	.35	.29	.19	.16	3.73
145	3.76	1.15	1.15	1.04	.85	.75	.65	.56	.45	.37	.32	.17	.13	3.12
146	3.26	1.14	1.14	.97	.69	.54	.46	.40	.30	.26	.20	.15	.13	3.02
147	3.96	2.39	2.15	1.49	1.23	1.01	.70	.45	.30	.24	.19	.17	.12	2.87
148	1.83	1.17	.93	.88	.78	.73	.62	.45	.30	.20	.15	.15	.08	1.83
149	2.15	1.17	.70	.59	.47	.41	.35	.32	.28	.20	.14	.10	.07	1.57
150	1.71	1.17	.93	.76	.70	.64	.58	.54	.47	.31	.25	.14	.07	1.71
152	1.72	.85	.68	.62	.60	.57	.53	.46	.31	.21	.14	.08	.04	1.08

[1] See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1941-42

Storm[1/]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
159	0.91	0.60	0.48	0.36	0.28	0.24	0.16	0.10				0.04	0.04	0.88
163	.62	.39	.38	.30	.30	.30	.24	.22	0.14	0.14	0.10	.05	.03	.62
164	2.01	.90	.72	.62	.50	.43	.39	.33	.23	.17	.14	.09	.08	1.88
165	.88	2.40	1.80	1.20	1.08	.90	.74	.66	.37	.22	.15	.07	.04	.88
166	.65		.24	.24	.24	.21	.20	.16	.11	.10	.08	.04	.03	.65
167	2.72	1.20	.72	.54	.48	.42	.36	.34	.23	.16	.15	.13	.08	1.82
169	1.56	1.23	.98	.80	.70	.68	.68	.41	.23	.14	.13	.10	.06	1.56
171	1.09	.48	.48	.24	.24	.24	.18	.14	.14	.12	.10	.08	.04	.94
172	.94	.42	.36	.31	.27	.24	.18	.15	.11	.10	.08	.05	.03	.82
177	.55	.66	.42	.33	.33	.32	.30	.26	.16	.08	.07	.04	.02	.55

[1/] See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1942-43

Storm[1/]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
178	0.91	1.20	1.08	0.72	0.60	0.48	0.36	0.28	0.26	0.21	0.15	0.08	0.04	0.90
179	.93	.90	.60	.42	.32	.30	.24	.24	.19	.12	.12	.08	.04	.93
180	.67	.13	.13	.13	.13	.13	.13	.12	.10	.09	.07	.06	.03	.67
181	1.45	1.80	1.20	.84	.69	.63	.51	.28	.18	.13	.13	.09	.04	1.05
182	20.90	1.19	1.19	1.07	1.03	.95	.95	.95	.88	.82	.79	.74 ~~.62~~	.63 ~~.44~~	15.03 ~~10.50~~
183	1.51	.60	.60	.42	.40	.40	.32	.19	.14	.13	.12	.09	.05	1.23
184	1.02	.90	.76	.43	.33	.26	.19	.13	.09	.08	.07	.05	.04	.92
185	.65	.60	.42	.30	.25	.22	.20	.18	.16	.12	.08	.05	.03	.65
186	6.45	2.40	1.52	1.14	1.00	.85	.74	.62	.59	.44	.34	.27	.16	3.94
187	6.94	2.40	1.31	1.25	.92	.75	.60	.41	.29	.28	.20	.16	.15	3.68
188	.66	.66	.36	.25	.20	.18	.16	.13	.11	.09	.08	.05	.03	.66
190	1.54	1.20	1.02	.64	.49	.41	.33	.29	.20	.12	.11	.10	.06	1.53
191	.78	.93	.76	.50	.47	.39	.28	.18	.13	.09	.07	.04	.03	.75

1/ See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1943-44

Storm[1]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
196	0.29	0.42	0.29	0.19	0.15	0.13	0.11	0.08	0.05	0.05	0.05	0.02	0.01	0.29
198	5.09	.93	.76	.69	.67	.61	.51	.38	.29	.27	.26	.20	.17	4.04
199	3.51	1.26	1.26	.94	.81	.72	.62	.50	.41	.29	.21	.11	.06	1.39
200	1.16	.40	.40	.36	.32	.31	.27	.21	.13	.08	.05	.03	.02	.53
202	.85	.96	.96	.70	.54	.44	.35	.29	.18	.13	.12	.07	.04	.85
205	1.24	.63	.42	.41	.38	.36	.34	.31	.27	.27	.19	.10	.05	1.24
206	.91	.84	.62	.46	.43	.40	.35	.29	.21	.14	.12	.08	.04	.91
207	.47	.93	.60	.40	.30	.25	.17	.09	.07	.05	.04	.02	.02	.47
209	11.02	1.44	1.08	.96	.88	.84	.74	.66	.59	.54	.49	.39	.26	6.36
210	.72	.60	.40	.30	.24	.21	.19	.14	.11	.07	.05	.03	.02	.42
211	2.38	1.26	1.13	.88	.70	.63	.56	.37	.32	.16	.13	.09	.07	1.65
213	.73	.33	.32	.29	.21	.18	.14	.12	.08	.07	.05	.04	.02	.60
215	1.49	.69	.64	.59	.50	.46	.41	.32	.26	.22	.17	.09	.05	1.31

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[1] See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1944-45

Storm[1]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
219	1.28	1.02	0.76	0.55	0.49	0.41	0.32	0.30	0.26	0.18	0.14	0.08	0.05	1.24
220	8.34	4.56	2.62	1.96	1.46	1.20	1.06	.97	.63	.43	.34	.30	.22	5.37
221	1.39	.36	.34	.30	.30	.28	.22	.19	.13	.11	.09	.06	.05	1.26
223	1.37	1.20	1.20	.92	.80	.68	.60	.50	.34	.21	.14	.07	.04	.86
224	.64	.32	.29	.23	.22	.22	.20	.16	.13	.08	.06	.05	.03	.64
225	6.18	2.19	1.60	1.09	.84	.74	.64	.53	.40	.37	.34	.23	.15	3.67
226	.53	.66	.53	.42	.32	.26	.18	.12	.08	.05	.04	.03	.01	.33
227	2.58	.90	.72	.48	.48	.46	.43	.32	.18	.10	.07	.04	.03	.81
228	2.46	.90	.72	.53	.45	.40	.39	.36	.35	.31	.30	.18	.10	2.39
229	.51	.14	.14	.14	.13	.13	.12	.11	.08	.07	.06	.04	.02	.51
230	.86	.78	.76	.66	.64	.63	.53	.30	.18	.12	.08	.07	.04	.86
231	.72	.24	.24	.19	.17	.16	.16	.13	.09	.08	.07	.06	.03	.72
232	.80	.63	.50	.46	.42	.32	.22	.17	.14	.09	.07	.04	.03	.80
233	.50	.63	.59	.53	.46	.42	.37	.28	.20	.11	.08	.04	.02	.50
235	.57	.21	.20	.14	.14	.13	.13	.11	.08	.05	.04	.03	.02	.55

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1945-46

Storm[1]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
236	.60	3.90	1.68	0.96	0.76	0.72	0.58	0.36	0.23	0.13	0.09	0.05	0.02	0.60
238	.51	.18	.18	.18	.12	.09	.08	.05	.04	.03	.03	.02	.02	.36
239	.49	.30	.24	.24	.24	.18	.12	.09	.07	.05	.04	.04	.02	.48
241	13.00	2.70	2.64	2.34	2.04	1.86	1.50	1.13	.85	.62	.47	.42	.32	7.75
243	2.15	2.40	2.28	1.26	1.16	.90	.74	.66	.53	.44	.33	.18	.09	2.15
245	.65	.96	.96	.54	.36	.27	.24	.21	.19	.14	.10	.05	.03	.65
246	1.01	.36	.36	.24	.24	.24	.18	.12	.10	.08	.07	.04	.03	.67
247	6.45	2.70	1.56	1.20	.88	.69	.64	.51	.42	.42	.42	.34	.20	4.90

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[1] See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1946-47

Storm[1/]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
251	1.62	1.80	0.84	0.60	0.44	0.39	0.38	0.32	0.26	0.22	0.20	0.12	0.07	1.62
252	.62	1.02	.96	.60	.56	.56	.56	.37	.22	.15	.10	.05	.03	.62
254	.98	.75	.72	.42	.32	.27	.20	.13	.10	.10	.08	.05	.04	.85
255	5.98	1.20	1.08	.84	.60	.60	.44	.38	.32	.27	.25	.17	.12	2.97
256	4.40	.90	.84	.72	.72	.60	.58	.52	.48	.46	.42	.33	.18	4.40
257	1.74	1.80	.96	.60	.60	.54	.46	.40	.28	.21	.18	.13	.07	1.74
258	.48	.72	.72	.60	.44	.33	.30	.16	.08	.05	.05	.04	.02	.48
259	5.40	2.10	1.60	1.14	.96	.93	.76	.39	.25	.21	.18	.13	.10	2.45
260	1.47	1.80	.84	.48	.44	.42	.42	.42	.38	.28	.22	.12	.06	1.47
261	.48	.57	.48	.45	.45	.45	.28	.21	.18	.11	.08	.04	.02	.48
262	1.07	2.70	1.56	.90	.80	.80	.72	.60	.44	.25	.17	.09	.04	1.05
264	.70	.75	.72	.72	.69	.69	.66	.38	.20	.10	.06	.04	.03	.60
265	.73	.30	.24	.18	.16	.15	.12	.11	.10	.06	.04	.03	.03	.73

[1/] See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1947-48

Storm[1]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
272	2.90	1.50	1.32	1.14	0.96	0.84	0.62	0.39	0.23	0.20	0.18	0.10	0.10	2.41
274	3.62	1.80	1.20	.90	.76	.66	.52	.49	.37	.26	.22	.16	.13	3.06
276	1.98	2.10	.84	.54	.52	.48	.40	.39	.26	.22	.15	.11	.07	1.65
277	.67	1.50	.60	.30	.30	.30	.20	.14	.13	.12	.08	.04	.03	.67
279	.98	2.70	1.44	.90	.88	.72	.60	.44	.32	.22	.16	.08	.04	.98
280	1.57	1.80	1.08	.72	.52	.42	.36	.33	.25	.23	.17	.10	.06	1.47
283	1.65	3.00	1.92	1.50	1.24	.99	.76	.49	.36	.30	.27	.14	.07	1.65

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[1] See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1948-49

Storm[1/]		Rate in inches per hour for time interval of--												Maximum 24-hour Amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
287	0.54	0.78	0.78	0.78	0.64	0.56	0.56	0.43	0.26	0.13	0.09	0.05	0.02	0.54
288	1.78	.96	.96	.56	.48	.48	.48	.30	.22	.16	.14	.09	.07	1.78
290	1.24	.90	.72	.66	.52	.42	.30	.22	.17	.13	.12	.10	.05	1.24
291	1.40	1.50	.60	.30	.24	.18	.15	.15	.09	.05	.04	.04	.02	.55
292	2.28	.75	.72	.42	.32	.30	.26	.19	.16	.13	.13	.13	.09	2.24
293	.99	.68	.68	.66	.52	.42	.30	.16	.13	.11	.10	.07	.04	.92
296	.65	.90	.30	.30	.24	.22	.22	.19	.15	.12	.11	.05	.03	.65
297	.93	.90	.72	.36	.36	.27	.18	.18	.14	.09	.07	.07	.04	.93
298	1.19	.60	.60	.48	.40	.33	.30	.22	.21	.19	.14	.08	.05	1.11
299	.71	.48	.48	.48	.36	.30	.22	.20	.14	.14	.12	.06	.03	.71
301	.66	.40	.36	.36	.28	.24	.18	.16	.14	.10	.10	.06	.03	.66
305	1.79	.36	.36	.24	.20	.18	.14	.08	.06	.04	.04	.04	.02	.53

[1/] See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1949-50

Storm[1]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
307	3.87	2.70	1.20	0.84	0.76	0.72	0.66	0.51	0.50	0.37	0.33	0.25	0.16	3.87
308	.54	.30	.18	.16	.16	.16	.16	.14	.12	.12	.08	.04	.02	.43
309	5.42	1.14	1.14	1.14	.84	.72	.60	.54	.49	.39	.34	.26	.20	4.68
311	1.56	.60	.60	.60	.60	.60	.60	.55	.43	.32	.23	.13	.06	1.56
312	1.11	.60	.36	.30	.28	.26	.26	.25	.20	.18	.14	.07	.04	.89
314	.64	.12	.12	.12	.12	.12	.10	.08	.06	.06	.06	.04	.03	.64
315	2.56	3.00	1.80	1.20	1.08	.99	.78	.63	.46	.34	.27	.17	.10	2.29
316	.50	.15	.15	.15	.15	.15	.14	.09	.07	.07	.05	.04	.02	.50
317	1.74	.60	.60	.60	.56	.54	.54	.49	.36	.30	.27	.15	.07	1.74
318	1.87	1.50	1.44	1.02	.68	.54	.42	.35	.26	.22	.17	.13	.07	1.78

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[1] See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1950-51

Storm[1/]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
322	1.25	0.96	0.96	0.96	0.84	0.69	0.60	0.53	0.39	0.24	0.18	0.10	0.05	1.18
325	1.20	5.40	3.60	1.98	1.88	1.56	1.28	.80	.52	.28	.20	.10	.05	1.20
327	.64	.30	.24	.24	.20	.18	.18	.13	.09	.09	.08	.05	.03	.64
328	1.46	.45	.42	.42	.40	.36	.36	.36	.31	.24	.19	.10	.05	1.31
331	.84	1.20	.60	.51	.36	.36	.34	.28	.20	.13	.12	.07	.04	.84
332	.84	.48	.48	.36	.28	.28	.28	.20	.11	.09	.06	.06	.04	.84
333	.86	.60	.36	.36	.36	.27	.26	.25	.17	.10	.07	.04	.03	.71
334	1.00	.68	.68	.60	.52	.48	.34	.30	.26	.22	.16	.08	.04	1.00
335	1.58	1.02	.84	.72	.72	.60	.58	.56	.44	.33	.23	.12	.06	1.51

[1/] See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1951-52

Storm[1]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
337	1.80	1.80	0.96	0.78	0.64	0.57	0.50	0.42	0.36	0.30	0.26	0.13	0.08	1.80
338	2.73	2.10	1.08	.90	.68	.60	.50	.40	.35	.29	.23	.12	.10	2.51
340	2.22	1.50	1.50	1.50	1.08	1.05	.80	.63	.62	.41	.33	.19	.09	2.22
341	1.82	1.50	1.20	.90	.72	.57	.40	.28	.22	.18	.17	.12	.08	1.82
342	.58	.60	.36	.36	.36	.36	.30	.20	.14	.10	.09	.05	.02	.58
343	5.92	1.20	.96	.60	.56	.51	.50	.43	.40	.34	.30	.20	.17	4.01
344	.56	.30	.24	.24	.20	.18	.18	.17	.16	.12	.09	.04	.02	.54
345	3.43	1.50	1.20	.90	.80	.75	.60	.56	.44	.40	.34	.24	.14	3.43
346	7.54	1.50	1.20	1.20	.92	.84	.70	.62	.56	.43	.40	.30	.19	4.61
347	.86	.30	.24	.18	.16	.15	.14	.12	.12	.08	.08	.06	.04	.86
348	1.56	1.50	1.44	.78	.52	.45	.32	.25	.18	.17	.12	.08	.06	1.44
349	3.22	.60	.60	.60	.40	.39	.34	.30	.26	.25	.22	.20	.13	3.16
350	1.02	1.20	.60	.36	.28	.24	.20	.19	.17	.13	.13	.08	.04	1.02
352	3.29	1.80	.84	.48	.48	.48	.48	.36	.26	.24	.21	.13	.12	2.81
353	.98	.90	.84	.60	.48	.39	.36	.30	.20	.14	.14	.08	.04	.98
356	1.16	.60	.48	.42	.42	.30	.26	.23	.18	.13	.09	.06	.03	.74

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[1] See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1952-53

Storm[1]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
358	0.65	0.36	0.36	0.36	0.32	0.30	0.28	0.27	0.18	0.14	0.10	0.05	0.03	0.65
359	2.84	1.20	.96	.78	.72	.66	.62	.49	.40	.27	.19	.11	.08	1.90
361	.72	.45	.45	.45	.45	.45	.42	.37	.32	.18	.12	.06	.03	.72
362	1.71	6.30	2.76	1.80	1.28	1.14	.96	.67	.52	.35	.27	.14	.07	1.71
364	1.16	1.80	.84	.48	.44	.39	.36	.26	.24	.18	.15	.08	.05	1.16
365	.66	1.20	.84	.60	.60	.36	.30	.24	.17	.13	.10	.06	.03	.66
366	.79	.90	.72	.66	.64	.63	.48	.37	.27	.16	.11	.06	.03	.79
367	1.17		.36	.36	.36	.33	.28	.18	.16	.13	.11	.08	.05	1.16
369	.64	.30	.24	.24	.24	.21	.16	.14	.12	.10	.08	.05	.03	.64
370	.67	.30	.24	.24	.24	.24	.22	.17	.12	.07	.06	.03	.03	.67
371	1.36	.90	.60	.36	.32	.32	.32	.25	.24	.20	.20	.11	.06	1.36
372	.76	.36	.36	.24	.20	.18	.16	.15	.12	.08	.06	.03	.03	.71
373	.93	.60	.48	.36	.32	.30	.30	.23	.14	.08	.07	.07	.04	.93

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[1] See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1953-54

Storm[1]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
377	1.05	1.20	0.60	0.54	0.54	0.51	0.44	0.43	0.34	0.23	0.16	0.09	0.04	1.05
379	.78	.72	.72	.48	.44	.42	.38	.32	.22	.15	.11	.06	.03	.74
380	6.56	1.50	1.20	1.20	.96	.87	.74	.57	.54	.52	.50	.32	.24	5.69
381	4.76	2.10	1.80	1.20	.96	.84	.62	.50	.38	.37	.29	.25	.19	4.51
382	4.24	2.40	1.20	1.20	1.08	1.02	1.00	.67	.50	.50	.42	.29	.15	3.66
383	1.30		1.32	.96	.76	.66	.54	.45	.36	.26	.20	.10	.05	1.30
384	3.65	1.50	1.32	.78	.60	.51	.36	.18	.14	.12	.11	.10	.06	1.50
385	1.40	.60	.36	.36	.32	.30	.26	.22	.19	.19	.16	.12	.06	1.40

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[1] See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1954-55

Storm[1]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
387	2.68	2.40	2.28	1.98	1.40	1.20	0.96	0.67	0.48	0.38	0.32	0.20	0.11	2.64
390	1.35	.60	.48	.48	.48	.48	.46	.35	.32	.24	.18	.10	.06	1.32
391	.62	.36	.36	.36	.36	.33	.32	.22	.14	.12	.08	.05	.03	.62
392	1.14	.90	.48	.48	.44	.42	.36	.30	.22	.16	.14	.09	.05	1.14
393	.60	.30	.24	.18	.18	.18	.18	.16	.11	.10	.08	.05	.02	.60
394	1.91	.72	.72	.66	.52	.45	.44	.42	.32	.28	.22	.11	.08	1.91
395	1.27	.96	.96	.60	.40	.30	.20	.19	.18	.14	.14	.09	.05	1.27
396	1.95	1.20	1.20	1.08	.96	.75	.60	.35	.34	.27	.23	.15	.08	1.95
398	.74	.60	.36	.30	.28	.27	.20	.12	.10	.07	.05	.03	.02	.54
399	1.50	.72	.72	.42	.40	.33	.28	.23	.20	.16	.15	.10	.05	1.28
400	.98	2.40	1.08	.60	.56	.54	.42	.31	.18	.12	.11	.08	.04	.98
401	.61	.30	.24	.24	.20	.18	.14	.13	.10	.09	.08	.05	.03	.61
403	2.74	1.50	1.32	.84	.64	.57	.52	.39	.28	.28	.28	.18	.10	2.46
404	.72	2.10	1.44	.84	.60	.45	.30	.17	.11	.08	.07	.04	.03	.69

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[1] See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1955-56

Storm[1/]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
406	1.04	0.31	0.31	0.31	0.31	0.31	0.31	0.26	0.21	0.19	0.16	0.08	0.04	1.04
408	.80	2.40	1.97	1.12	.80	.60	.46	.28	.20	.14	.12	.07	.03	.80
413	10.01	1.50	1.20	.89	.81	.81	.79	.68	.62	.60	.57	.45	.29	7.06
416	1.42	.62	.62	.51	.46	.41	.36	.29	.22	.15	.13	.09	.06	1.38
418	2.31	.29	.29	.29	.29	.27	.24	.22	.19	.18	.17	.14	.09	2.05
419	1.12	.62	.42	.42	.42	.42	.42	.28	.22	.15	.12	.08	.04	1.05
420	1.30	1.64	1.25	.70	.57	.43	.28	.25	.12	.10	.08	.08	.05	1.28

[1/] See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1956-57

Storm[1]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
422	1.05	0.48	0.48	0.32	0.28	0.25	0.22	0.18	0.18	0.14	0.11	0.07	0.04	1.04
423	1.30	1.50	.80	.56	.44	.36	.28	.25	.19	.14	.12	.09	.05	1.30
425	.90	.60	.60	.53	.47	.44	.41	.35	.24	.18	.13	.07	.04	.90
426	3.70	1.80	1.44	.98	.81	.66	.56	.56	.43	.42	.36	.28	.15	3.70
428	2.19	.48	.48	.48	.39	.34	.30	.17	.14	.13	.11	.08	.04	.91
429	1.78	2.40	1.32	.96	.84	.70	.54	.36	.30	.29	.25	.14	.07	1.78
430	1.08	2.14	2.14	1.60	1.17	.90	.62	.39	.22	.13	.09	.08	.04	1.06
431	.90	2.25	1.92	1.26	1.01	.82	.62	.34	.30	.18	.13	.07	.04	.90
432	.64	.90	.78	.54	.46	.42	.35	.27	.21	.13	.09	.05	.03	.64
433	.90	.34	.34	.29	.27	.26	.26	.23	.20	.14	.10	.06	.04	.90
434	.99	.32	.32	.32	.32	.30	.28	.25	.24	.14	.09	.05	.03	.82
435	1.13	1.02	.80	.62	.54	.48	.40	.28	.19	.15	.10	.05	.04	1.06
436	1.46	1.00	.74	.56	.43	.37	.33	.29	.25	.19	.19	.12	.06	1.46

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[1] See "Storm Data" tables for dates.

MAXIMUM RAINFALL RATES
Tanbark Flat
Hydrologic year 1957-58

Storm[1]		Rate in inches per hour for time interval of--												Maximum 24-hour amount
		Minutes									Hours			
Number	Amount	2	5	10	15	20	30	60	120	240	6	12	24	
	Inches													Inches
439	1.58	3.00	1.37	0.84	0.61	0.50	0.40	0.38	0.32	0.16	0.15	0.11	0.07	1.58
440	.71	1.80	1.08	.71	.56	.46	.34	.21	.17	.09	.06	.05	.03	.71
441	1.08	4.50	3.76	2.20	1.61	1.74	1.40	.82	.42	.23	.15	.08	.04	1.03
443	.59	.60	.60	.54	.44	.38	.34	.28	.16	.09	.07	.05	.02	.59
444	1.63	2.10	1.20	1.01	.80	.67	.45	.36	.24	.20	.14	.09	.05	1.29
445	1.98	3.90	2.14	1.31	1.02	.98	.82	.61	.46	.36	.26	.14	.08	1.98
446	6.60	1.83	1.21	1.07	1.03	1.00	.92	.63	.38	.24	.24	.24	.18	4.20
447	3.77	1.32	.84	.87	.68	.53	.41	.36	.36	.34	.32	.28	.15	3.63
448	6.05	2.43	1.58	1.24	1.06	1.01	.75	.38	.32	.25	.25	.21	.16	3.88
449	2.21	2.01	1.54	1.18	.91	.75	.58	.41	.31	.26	.24	.18	.09	2.21
450	1.50	1.08	.66	.55	.45	.42	.40	.38	.34	.29	.24	.12	.06	1.50
452	1.42	2.01	1.27	.73	.60	.46	.36	.24	.20	.15	.11	.09	.06	1.40
453	.97	.73	.73	.69	.69	.55	.39	.24	.17	.15	.10	.05	.03	.64
454	3.16	1.50	.72	.72	.63	.58	.54	.41	.36	.27	.20	.18	.12	2.82
455	.81	1.00	.66	.41	.33	.28	.24	.16	.14	.11	.10	.07	.03	.81
456	.90	2.10	.91	.78	.57	.46	.38	.34	.28	.19	.15	.08	.04	.90
457	1.08	1.05	.72	.54	.52	.51	.46	.34	.20	.17	.17	.09	.04	1.08
458	4.51	7.20	2.93	1.51	1.05	.82	.69	.58	.40	.39	.37	.30	.18	4.37
459	3.67	1.50	1.10	.96	.92	.75	.72	.66	.58	.53	.44	.29	.15	3.53
460	2.27	1.95	1.32	.96	.72	.54	.40	.34	.22	.20	.15	.09	.09	2.09

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[1] See "Storm Data" tables for dates.

SECTION III

STORM DATA BY HYDROLOGIC YEARS

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1933-34

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start		Storm stop		Storm duration		Actual raining time		Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed		Avg. storm temp. °F.	Range in precipitation		Character of precipitation
	Date	Time	Date	Time	Hr.	Min.	Hr.	Min.					Storm avg.	Max. hourly		1500 ft IF-50	5200 ft IF-32	
											Inches	IPH	MPH			Inches		Rain unless otherwise noted
	1933																	
1	10/30	1900	10/31	0500	10	0	10	0	0		0.56		No record		51.5	0.75		
2	11/28	0100	11/28	1400	13	0	9	0	1	28	.65	0.20			43.5	.57		
3	11/29	1930	11/30	0330	8	0	8	0	0	1	.19	.05			35.0	.14		
3A	12/3	1500	12/3	1700	2	0	2	0	0	3	.02					.02		
4	12/12	1400	12/13	1500	25	0	25	0	0	9	5.20	.71			50.0	4.93		
5	12/14	1645	12/15	0300	10	15	4	0	1	1	.64	.24			40.0	.24		
6	12/15	1640	12/15	2230	5	50	5	50	0	0	.29	.13			40.0	.20		
7	12/30	0130	1/1	1730	64	0	56	0	1	15	11.25	.80			47.5	11.21		
	1934																	
8	1/23	2200	1/24	0400	6	0	3	0	1	22	.45	.43			40.0	.88		Rain, snow
8A	2/4		2/4								T							
8B	2/15	1710	2/15	1940	2	30	2	30	0	22	.07	.04				.07		
9	2/19	1500	2/20	0500	14	0	14	0	0	4	.72	.15			48.0	.77		
10	2/22	0740	2/24	0800	48	20	40	20	2	2	3.14	.47			47.0	2.00		
11	3/23	0200	3/23	0400	2	0	2	0	0	27	.10				47.0	.05		
12	4/14	1900	4/15	2400	29	0	10	0	2	22	.21				51.0	.09		
12A	4/23		4/23							8	.01							
12B	5/1	0900	5/1	1200	3	0	3	0	0	8	.05							
13	6/5	0520	6/5	2050	15	30	9	30	3	35	.56	.21			51.0	.87		
13A	6/13	2020	6/14	1640	20	20	20	20	0	8	.07					.02		
14	8/19	0940	8/19	1210	2	30	2	30	0	66	.10	.05				.51		
14A	9/22	0650	9/22	0800	1	10	1	10	0	34	.03							
15	9/23	0520	9/23	1010	4	50	4	50	0	1	.20	.08				.05		
Total											24.51					23.37		

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1934-35

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start		Storm stop		Storm duration		Actual raining time		Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed		Avg. storm temp. °F.	Range in precipitation		Character of precipitation
	Date	Time	Date	Time	Hr.	Min.	Hr.	Min.					Storm avg.	Max. hourly		1500 ft IF-50	5200 ft IF-32	
											Inches	IPH	MPH			Inches		Rain unless otherwise noted
	1934																	
16	10/6	0520	10/6	1140	6	20	3	20	1	13	0.10				66.0	0.08		
17	10/16	2350	10/18	1440	38	50	26	0	3	10	6.49	0.83			49.0	5.18		
17A	10/31	2340	11/1	0320	3	40	3	40	0	13	.06					.03		
18	11/15	1730	11/19	0600	84	30	54	0	5	14	2.65	.35	2.1		48.0	3.16		
19	12/7	2230	12/8	1330	15	0	13	0	1	18	.62	.15	3.3		50.5	.49		
20	12/12	0330	12/14	1230	57	0	51	30	2	4	5.14	.51			50.5	4.06		
21	12/27	2130	12/28	0830	11	0	11	0	0	13	1.01	.19	3.2		51.0	.90		
	1935																	
22	1/4	0610	1/5	1930	37	20	23	0	2	7	2.21	.53	4.3		41.0	1.52		
23	1/8	1900	1/10	0900	38	0	24	0	3	3	1.04	.10	2.8		44.0	.88		
24	1/14	2040	1/15	0930	12	50	12	50	0	4	1.65	.50	4.5		42.0	1.48		
25	1/18	1600	1/19	1020	18	20	13	20	2	3	1.12	.43	5.7		32.5	1.02		
26	2/4	0430	2/9	2120	136	50	77	0	8	16	3.14	.25	2.5		44.0	3.45		
27	2/14	0740	2/14	1030	2	50	2	50	0	5	.10				44.0	.10		
28	3/2	0140	3/2	1730	15	50	15	50	0	16	1.05	.73	4.8		41.0	1.13		
29	3/4	1600	3/5	0800	16	0	7	0	1	2	.54	.18	3.8		41.5	.60		
30	3/7	0750	3/9	0920	49	30	16	0	3	2	1.00	.15	2.4		35.0	.93		Some snow
30A	3/19	1340	3/19	1400	0	20	0	20	0	10	.06					.06		
31	3/21	1205	3/22	0800	19	55	4	0	1	2	.48	.23			34.5	.17		
32	3/23	1830	3/24	0200	7	30	7	30	0	1	.82	.19	2.4		36.5	.81		
33	4/4	2110	4/4	2230	1	20	1	20	0	11	.12				46.0	.17		
34	4/7	1210	4/8	1100	22	50	18	0	1	3	4.10	.82	6.1		48.0	3.26		
35	4/29	0700	4/30	1750	34	50	8	0	3	21	1.07	.23			44.0	.77		
35A	5/16	1700	5/16	2320	6	20	6	20	0	16	.07							
35B	5/28		5/28							12	.02							
35C	7/1	0001	7/1	1600	15	59				34	.03					.19		
35D	8/25	1515	8/25	1610	0	55	0	55	0	55	.09					.18		
35E	8/26	0210	8/26	0300	0	50	0	50	0	1	.02							
Total											34.80					30.62		

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1935-36

1 Storm number	2 Storm start: Date	3 Storm start: Time	4 Storm stop: Date	5 Storm stop: Time	6 Storm duration: Hr.	6 Storm duration: Min.	7 Actual raining time: Hr.	7 Actual raining time: Min.	8 Breaks in storm	9 Days since last rain	10 Storm total	11 Max. hrly rain rate	12 Wind speed: Storm avg.	13 Wind speed: Max. hourly	14 Avg. storm temp. °F.	15 Range in precipitation: 1500 ft: IF-50	15 Range in precipitation: 5200 ft: IF-32	16 Character of precipitation
											Inches	IPH	MPH			Inches		
	1935																	Rain unless otherwise noted
36	10/1	0020	10/2	0500	28	40	8	40	3	36	0.16				55.0	0.23	0.01	
37	10/14	1945	10/14	2245	3	0	3	0	0	12	.27	0.16			52.0	.25	.27	
38	11/2	0400	11/2	0730	3	30	3	30	0	19	.11				43.0	.08	.41	
39	11/17	1330	11/18	0830	19	0	11	0	2	15	.37	.09			39.5	.38		
39A	11/22	1230	11/22	1330	1	0	1	0	0	4	.01					.02	.09	
40	12/3	2240	12/4	0530	6	50	3	50	2	11	.24	.11			42.5	.35		
41	12/29	0700	12/29	1415	7	15	5	15	1	25	.92		4.6		49.5	.83	.76	
	1936																	
41A	1/11	1415	1/11	1840	4	25	4	25	0	13	.04					.04	.02	
41B	1/28	1315	1/28	1745	4	30	4	30	0	17	.05					.10	.14	
41C	1/29	0215	1/29	0405	1	50	1	50	0	1	.03						4.90	
42	1/31	2230	2/2	1120	36	50	31	50	1	2	4.40	.66	6.1		46.5	3.04		
43	2/11	0001	2/16	1640	136	39	70	40	7	9	10.03	.95	3.3		43.4	9.37	11.89	
44	2/17	0250	2/18	2030	41	40	10	0	3	1	.69	.19	4.8		42.0	.79		
45	2/22	1900	2/24	0900	38	0	15	0	5	4	1.77	.63	5.8		42.0	1.66	2.11	Some hail
46	3/21	0150	3/22	0400	26	10	17	10	4	26	.27				47.0	.21	.18	Snow
47	3/24	1110	3/24	1615	5	5	5	5	0	2	.59		3.1		36.0	.66	.65	Melting snow
48	3/30	1740	3/31	0400	10	20	8	20	1	6	1.78	.35	6.0		42.0	1.51	2.16	
49	4/3	1230	4/4	1500	26	30	22	30	1	3	2.55	.68	4.1		43.0	1.80	2.58	
49A	7/7		7/7							94	T					.01	.01	
49B	7/9		7/10							2	T					.05		
49C	9/19		9/19							71	T					.04		
Total											24.28					21.42	26.18	

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1936-37

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start Date	Storm start Time	Storm stop Date	Storm stop Time	Storm duration Hr.	Storm duration Min.	Actual raining time Hr.	Actual raining time Min.	Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed Storm avg.	Wind speed Max. hourly	Avg. storm temp. °F.	Range in precipitation 1500 ft IP-50	Range in precipitation 5200 ft IP-32	Character of precipitation
											Inches	IPH	MPH			Inches		
	1936																	Rain unless otherwise noted
50	10/16	0830	10/18	0700	46	30	23	0	2	27	1.30	0.27	3.5		53.2	1.29	2.86	
51	10/29	2000	10/31	0530	33	30	12	0	3	11	1.72	.30	1.9		49.3	1.09	2.02	
51A	11/21	2230	11/23	0630	32	0	11	0	4	21	.17				52.1	.17	.52	
52	12/3	1800	12/4	1300	19	0	16	0	1	10	.23				41.2	.17	.48	
53	12/14	1700	12/16	0935	40	35	36	0	1	10	4.07	.33	2.3		47.4	3.03	6.33	
54	12/25	0230	12/29	0900	102	30	38	0	6	9	5.57	.66	4.2		40.1	4.29	10.79	
55	12/30	1330	12/31	1300	23	30	23	30	0	1	4.64	.71	5.2		40.8	2.14		
	1937																	
56	1/5	0800	1/8	2200	86	0	26	0	3	5	1.82	.28	3.4		34.8	1.64	2.30	Snow
57	1/12	0700	1/12	2200	15	0	11	0	1	4	.68	.25	1.6		36.0	1.24	1.44	Snow
57A	1/19		1/19							7	.03						3.56	
58	1/28	1700	1/31	0930	64	30	28	0	3	9	2.95	.52	3.7		37.1	2.25		
59	2/5	1900	2/7	0930	38	30	38	30	0	5	4.60	.45	2.0		47.1	4.14	4.13	
59A	2/11	1700	2/11	1900	2	0	2	0	0	4	.04						5.90	
60	2/13	1300	2/15	0900	44	0	33	0	2	2	4.45	.42	2.6		47.6	3.71		
61	2/24	1730	2/25	1530	22	0	16	30	1	9	1.28	.21	2.5		41.5	1.62	1.67	Hail, snow
62	3/12	0200	3/13	0630	28	30	28	30	0	15	4.78	.47	7.4		45.9	4.84	7.23	
63	3/15	1200	3/16	1600	28	0	10	34	1	2	1.43	.38	4.4		50.2			
64	3/17	2030	3/18	0330	7	0	5	0	1	1	.32	.13			40.5	.34	.51	
65	3/21	2330	3/22	1700	17	30	17	30	0	3	1.42	.29	3.1		38.0	1.38	1.27	Snow
66	3/24	1330	3/24	2130	8	0	8	0	0	2	.54	.16	1.9		39.4	.55	.65	
67	3/27	2030	3/27	2130	1	0	1	0	0	3	.38	.38			35.0	.45	.25	Hail
68	4/1	2000	4/2	0800	12	0	10	0	1	5	.40	.18			43.5			
69	4/26	2100	4/26	2400	3	0	3	0	0	24	.24	.16				.39	.25	
70	5/24	1830	5/26	1700	46	30	16	0	7	28	.57	.25	1.5		53.0	.26	.20	
71	5/28	0230	5/31	0700	76	30	25	0	3	2	.25				51.0	.22	.11	
71A	6/4	2000	6/6	1030	38	30	14	0	2	4	.06					.00		
Total											43.94					35.21	52.47	

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1937-38

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start Date	Storm start Time	Storm stop Date	Storm stop Time	Storm duration Hr.	Storm duration Min.	Actual raining time Hr.	Actual raining time Min.	Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed Storm avg.	Wind speed Max. hourly	Avg. storm temp. °F.	Range in precipitation 1500 ft IF-50	Range in precipitation 5200 ft IF-32	Character of precipitation
											Inches	IPH	MPH			Inches		
	1937																	Rain unless otherwise noted
71B	11/7	0230	11/7	0900	6	30	2	0	1	154	0.04					0.02		
72	12/9	1830	12/11	2100	50	30	35	0	1	32	3.14	0.39	1.5		54.1	3.26	3.43	
73	12/22	2200	12/23	1130	13	30	13	30	0	11	1.53	.41	3.3		44.7	.68	1.40	
74	12/26	0200	12/26	1930	17	30	15	0	1	3	.80	.20	1.8		49.2	.70	.94	
	1938																	
75	1/14	1700	1/15	1130	18	30	16	0	1	19	2.62	1.20	3.5		49.9	2.20	3.84	
76	1/18	1300	1/19	0300	14	0	10	0	2	3	.29				44.8)	.35)	.65	
77	1/19	1700	1/19	2000	3	0	3	0	0	0	.24				43.0)		7.04)	
78	1/28	1700	1/29	1130	18	30	8	0	2	9	.31				41.0	.28)		
79	1/31	2200	2/1	1030	12	30	12	30	0	2	1.70	.33	4.9		44.8	1.87)		
80	2/2	1500	2/4	1400	47	0	22	12	2	1	3.74	.34	6.0		43.5	2.34)		
81	2/8	2030	2/10	0500	32	30	27	0	1	4	1.71	.25	4.5		45.8	1.65)	5.01	Sleet
82	2/10	2300	2/12	1000	35	0	26	0	2	0	2.47	.73	5.8		40.8	1.85)		Snow
82A	2/14	0800	2/14	1000	2	0	2	0	0	2	.04					.04		
83	2/18	1500	2/19	0330	12	30	12	30	0	4	.72	.17	2.8		40.8	.62	.83	
84	2/27	0130	3/1	0330	50	0	48	0	1	8	8.27	1.20	3.8		51.7	5.68)	25.13	
85	3/1	2300	3/3	2100	46	0	39	0	1	0	12.93	1.17	6.3		47.7	8.65)		Hail
86	3/7	2300	3/8	1600	17	0	7	54	2	4	.83	.18	2.0		43.3	.56)	5.23	Hail, sleet
87	3/11	1800	3/13	1130	41	30	29	0	1	3	4.01	.45	5.7		48.6	2.92)		
88	3/28	1800	3/28	2400	6	0	6	0	0	15	.10				41.2	.09	.14	
89	4/12	2030	4/13	0005	3	35	3	35	0	15	.25				40.7	.16	.32	
90	4/24	0830	4/25	1130	27	0	12	43	3	11	1.00	.22	2.0		47.2	1.11	1.23	
91	4/29	0700	5/2	1930	84	30	30	0	7	4	.91	.12	1.9		44.8	.66	1.23	
92	5/15	2130	5/17	0330	30	0	11	0	2	13	.20				48.7	.03	.26	
93	6/9	0200	6/11	0200	48	0	24	0	2	23	.22				50.6	.14	.07	
93A	7/13	0750	7/13	0800	0	10				32	T					.00	.17	
93B	8/28	1319	8/29							46	T							
93C	9/17	2100	9/17	2120	0	20	0	20	0	19	.06					.03	.04	
Total											48.13					35.89	56.96	

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1938-39

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start		Storm stop		Storm duration		Actual raining time		Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed		Avg. storm temp.	Range in precipitation		Character of precipitation
	Date	Time	Date	Time	Hr.	Min.	Hr.	Min.					Storm avg.	Max. hourly	°F.	1500 ft IF-50	5200 ft IF-32	
											Inches	IPH	MPH			Inches		
	1938																	Rain unless otherwise noted
93D	10/1	2100	10/1	2200	1	0	1	0	0	14	0.02	0.02					0.56	
94	10/15	0010	10/15	1000	9	50	9	50	0	14	.36	.11			52.3	0.41		
94A	11/10	1930	11/10	2050	1	20	1	20	0	26	.05	.04				.01		
95	12/14	0730	12/16	0400	44	30	24	0	4	34	1.77	.43	2.3		49.5	1.73	11.88	
96	12/17	1530	12/21	0300	83	30	69	0	4	1	7.27	.53	1.6		45.5	6.63		
	1939																	
96A	1/2	1330	1/2	1700	3	30	3	30	0	12	.01	.01				.03	2.11	
97	1/5	0800	1/5	1910	11	10	11	10	0	3	2.35	.77	3.9		42.7	1.65		
98	1/21	0050	1/21	2020	19	30	19	30	0	16	.93	.15	2.0		41.1	1.53	1.41	
98A	1/27	2200	1/28	0330	5	30	5	30	0	6	.06	.03				.13	.84	
99	1/30	1430	2/1	1100	44	30	20	50	2	2	.76	.14	1.4		34.4	.69		Snow
100	2/3	0900	2/3	2300	14	0	14	0	0	2	1.12	.29	1.1		34.5	1.36	2.15	Snow 4" at Tanbark
101	2/7	2250	2/8	0640	7	50	7	50	0	4	.93	.32	4.7		35.5	.89		
101A	2/10	0510	2/10	1000	4	50	4	50	0	2	.06	.02					.06	
101B	2/19	0530	2/19	0700	1	30	1	30	0	9	.04	.02						
102	3/9	1850	3/10	0300	8	10	8	10	0	18	1.57	.44	6.5		41.0	1.11	1.58	Snow
103	3/19	2310	3/20	0340	4	30	4	30	0	9	.32	.12			53.5	.31	.29	
103A	3/22	2100	3/23	0400	7	0	7	0	0	2	.02	T						
104	3/25	2230	3/28	0500	54	30	40	0	2	2	2.38	.45	2.1		42.0	1.40	1.86	
105	4/1	2050	4/2	0550	9	0	9	0	0	4	.85	.22	2.8		49.0	.70	.81	
106	4/13	0700	4/14	0400	21	0	8	0	2	11	.14	.07			40.5		.20	
106A	4/23	0030	4/23	0220	1	50	1	50	0	9	.05	.03				.02		
107	5/13	1250	5/14	0230	13	40	3	30	3	20	.16	.08			51.5	.01	.08	
107A	5/15	0200	5/15	0400	2	0	2	0	0	1	.02	.01						
108	9/10	1945	9/12	0050	29	5	7	27	3	118	.30	.09			69.0	.50	.18	
109	9/21	1345	9/21	1600	2	15	2	15	0	9	.13	.07			83.5	.35	.08	
110	9/24	1100	9/26	0212	39	12	37	12	1	3	5.25	.48	6.1		62.0	6.68	11.00	
Total											26.92					26.14	35.09	

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic year 1939-40

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start		Storm stop		Storm duration		Actual raining time		Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed		Avg. Storm temp.	Range in precipitation		Character of precipitation
	Date	Time	Date	Time	Hr.	Min.	Hr.	Min.					Storm avg.	Max. hourly	°F.	1500 ft IF-50	5200 ft IF-32	
											Inches	IPH	MPH			Inches		Rain unless otherwise noted
	1939																	
111	10/2	0011	10/3	1510	38	59	6	0	4	6	0.10	0.01			53.0	0.24	0.12	
112	10/6	1420	10/8	1535	49	15	10	0	6	3	.45	.10			52.0	.35	.68	
112A	10/24	2130	10/24	2250	1	20	1	20	0	16	.04	.02						
113	11/8	0838	11/9	0816	23	38	10	19	3	15	.32	.06			51.0	.24	.41	
113A	12/5	2115	12/5	2300	1	45	1	45	0	26	.09	.06				.08	.06	
113B	12/11	0200	12/11	0930	7	30	2	0	1	6	.04	T				.01	.06	
114	12/23	0815	12/23	1930	11	15	9	0	1	12	.92	.40	4.4		43.0	.75	1.20	Snow Fern
	1940																	
115	1/4	0530	1/4	1930	14	0	7	0	2	12	.54	.11	1.8		50.0	.90	.62	
116	1/6	0530	1/12	0542	144	12	53	45	13	2	5.61	.57	2.0		47.5	6.02	7.16	
117	1/23	1432	1/23	1914	4	42	4	42	0	11	.87	.44	4.3		44.5	.76	.84	
118	1/31	0920	2/4	0900	95	40	42	0	9	8	3.59	.58	2.8		46.0	2.89	3.51	
118A	2/12	1900	2/12	1933	0	33	0	33	0	8	.02	.02					.00	
119	2/14	0800	2/14	1733	9	33	9	33	0	2	.40	.10			49.0	.34	.46	
120	2/22	0658	2/23	1815	35	17	9	20	3	8	.26	.06			50.0	.20	.42	
121	2/25	1220	2/26	0350	15	30	15	30	0	2	2.51	.58	5.1		53.5	2.18	3.39	
122	2/28	2115	2/29	1235	15	20	8	0	1	2	1.19	.37	2.8		48.5	.75	.98	
122A	3/10		3/10							10	T					T	.00	
122B	3/19		3/19							9	T					.01	.03	
123	3/25	1830	3/27	0940	39	10	23	10	2	6	.26	.05			49.0	.20	.20	
124	3/31	0108	4/1	0826	31	18	28	0	1	4	2.07	.29	1.9		44.0	2.08	2.96	
124A	4/4	1430	4/4	1512	0	42	0	42	0	3	.02					.01	T	
125	4/15	0040	4/15	1819	17	39	7	39	1	11	.37	.29			48.5	.61	.25	
126	4/25	2330	4/26	1938	20	8	16	24	1	10	2.21	.53	2.5		42.0	2.25	2.48	
127	5/18	1247	5/18	1700	4	13	1	30	1	22	.11	.07			60.0	T	.00	
127A	7/9		7/9							52	T					T	.00	
127B	9/26		9/26							79	T					T	.00	
Total											21.99					20.87	25.83	

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1940-41

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start		Storm stop		Storm duration		Actual raining time		Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed		Avg. storm temp.	Range in precipitation		Character of precipitation
	Date	Time	Date	Time	Hr.	Min.	Hr.	Min.					Storm avg.	Max. hourly	°F.	1500 ft IF-50	5200 ft IF-32	
											Inches	IPH	MPH			Inches		
	1940																	Rain unless otherwise noted
127C	10/8	1700	10/8	1900	2	0	2	0	0	12	0.06	0.02				0.02	0.00	
128	10/25	1030	10/26	2226	35	56	18	56	3	17	2.47	.39	2.1		55.7	2.23	2.47	
129	11/17	0910	11/18	0510	20	0	16	45	2	22	1.87	.32	1.3		41.7	1.34	1.71	
130	12/11	2140	12/12	0200	4	20	4	20	0	23	.32	.13			40.0	.21	.50	
131	12/16	0330	12/17	0845	29	15	24	34	1	4	2.92	.33	2.8		47.6	2.60	4.02	
132	12/18	1421	12/18	1742	3	21	3	21	0	1	.31	.14			55.0	.33	.22	
133	12/23	0037	12/23	1124	10	47	10	47	0	5	1.94	.52	2.8		42.0	1.97	2.34	
134	12/24	0023	12/24	1836	18	13	13	46	2	1	2.22	.42	2.3		36.0	2.07	2.39	
135	12/28	2106	12/29	0938	12	32	12	32	0	4	.46	.10			40.8	.48	.92	
136	12/30	1804	12/30	2111	3	7	3	7	0	1	.52	.36	1.9		34.0	.94	.56	Rain, snow
	1941																	
136A	1/4	1503	1/4	1916	4	13	2	30	1	5	.05	.02				.05	.07	
136B	1/7		1/7							3	T							
137	1/10	0530	1/10	1215	6	45	6	45	0	3	.58	.18	3.7		67.5	.45	.75	
137A	1/14	0100	1/14	0430	3	30	3	30	0	4	.08	.04				.14	.08	
138	1/21	1753	1/22	0153	8	0	8	0	0	7	.69	.22	1.8		49.7	.71	.66	
139	1/23	0600	1/24	1130	29	30	20	33	3	1	1.53	.24	1.4		46.5	1.35	1.72	
140	1/25	2203	1/26	0706	9	3	9	3	0	1	.26				44.0	.22	.43	
141	2/6	0407	2/6	1028	6	21	6	21	0	11	.82	.27	4.5		48.5	.66	.67	
142	2/11	0913	2/11	2138	12	25	8	25	2	5	1.54	.48	6.4		49.6	1.36	1.93	
143	2/14	1238	2/17	0616	65	38	30	39	5	3	2.46	.20	2.0		35.4	2.22	3.44	
144	2/19	1049	2/24	1354	123	5	58	35	9	2	6.56	.79	2.8		42.9	5.94	8.28	
145	2/28	1409	3/2	0910	43	1	38	25	3	4	3.76	.56	2.1		48.5	2.68	3.99	

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1940-41 (Cont'd)

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start Date	Storm start Time	Storm stop Date	Storm stop Time	Storm duration Hr.	Storm duration Min.	Actual raining time Hr.	Actual raining time Min.	Breaks in storm	Days since last rain	Storm total	Max. hrly. rain rate	Wind speed Storm avg.	Wind speed Max. hourly	Avg. storm temp. °F.	Range in precipitation 1500 ft: IF-50	Range in precipitation 5200 ft: IF-32	Character of precipitation
											Inches	IPH	MPH			Inches		Rain unless otherwise noted
	1941 (Cont'd)																	
146	3/3	1945	3/5	0725	35	40	26	25	1	1	3.26	.40	4.0		56.9	2.91	4.56	Rain, snow
147	3/11	1553	3/14	1830	74	37	38	43	6	6	3.96	.45	2.7		40.0	3.14	5.88	
148	3/28	1610	3/29	0431	12	21	12	21	0	14	1.83	.45	3.1		52.0	1.70	2.56	
149	3/31	0947	4/2	1920	57	33	21	6	7	2	2.15	.32	2.4		52.4	2.13	2.87	Rain, snow
150	4/4	1424	4/4	2215	7	51	7	51	0	2	1.71	.54	5.4		45.2	1.04	2.14	
151	4/9	1746	4/9	2318	5	32	5	32	0	5	.95	.28	6.0		48.2)	1.59	.70	Rain, snow
152	4/10	1518	4/14	0720	88	2	25	27	7	1	1.72	.46	2.4		47.8)		2.14	
153	4/17	1955	4/17	2020	0	25	0	25	0	3	.15	.15			45.0	.10	.03	
154	4/29	2039	4/30	1830	21	51	21	51	0	12	.78	.11	2.9		45.1	.75	1.64	
155	5/2	1820	5/3	0508	10	48	8	0	1	2	.15	.03			50.4	.04	.07	
155A	5/18	0300	5/18	0820	5	20	2	30	1	15	.02					.01	.02	
155B	5/27		5/27							9	T							
155C	6/2		6/2							6	T							
156	6/6	1823	6/7	0142	7	19	7	19	0	4	.10	.02			47.8	.07	.12	
156A	6/8		6/8							1	T						.05	
156B	7/25		7/25							47	T							
156C	7/26		7/26							1	T							
156D	8/5		8/5							10	T							
156E	8/10		8/10							5	T							
156F	8/15	0900	8/15	1200	3	0				5	.03	.01				.01		
Total											48.23					41.46	59.93	

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1941-42

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start Date	Storm start Time	Storm stop Date	Storm stop Time	Storm duration Hr.	Storm duration Min.	Actual raining time Hr.	Actual raining time Min.	Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed Storm avg.	Wind speed Max. hourly	Avg. storm temp. °F.	Range in precipitation 1500 ft IF-50	Range in precipitation 5200 ft IF-32	Character of precipitation
											Inches	IPH	MPH			Inches		Rain unless otherwise noted
	1941																	
157	10/12	0200	10/12	0600	4	0	4	0	0	58	0.14	0.04			54.5	0.12	0.29	
158	10/19	1530	10/20	2100	29	30	19	0	1	7	.42	.04			44.1	1.53	.82	
159	10/21	1552	10/24	0701	63	9	26	0	7	1	.91	.10	2.2		46.7		1.60	
160	10/27	0950	10/27	1353	4	3	2	0	1	3	.27	.20			52.0	.24	.21	
161	11/11	2053	11/12	0337	6	44	6	44	0	15	.37	.14				.43	.49	
161A	11/16	2153	11/17	0832	10	39	1	30	1	4	.06	.01				.23	.10	
162	11/29	1330	11/29	2347	10	17	6	0	1	12	.20	.07			52.2	.14	.39	
163	12/3	1004	12/3	1830	8	26	8	26	0	4	.62	.22	1.8		47.6	.58	.60	
164	12/9	1208	12/10	1721	29	13	20	29	4	6	2.01	.33	2.7		43.6	1.98	3.54	
165	12/23	1207	12/23	1519	3	12	3	12	0	13	.88	.66	3.6		40.0	.55	.71	Hail
166	12/25	1417	12/26	0809	17	52	9	25	1	2	.65	.16	1.9		34.0	.66	.97	Snow
167	12/28	1344	1/1	1525	97	41	34	46	10	2	2.72	.34	2.3		38.3	2.01	3.02	Snow
	1942																	
168	1/22	0154	1/22	0630	4	46	4	46	0	21	.11	.03			45.3	.10	.67	
169	2/21	0917	2/22	0423	19	6	17	6	1	30	1.56	.41	3.5		40.4	1.30	2.02	
169A	2/27	0045	2/27	0601	5	16	2	30	1	5	.06	.04				.13	.02	
170	3/11	1120	3/15	0205	86	45	57	0	8	12	1.87		1.4		39.3	2.04	1.98	Snow Tanbark
171	4/3	1656	4/6	1600	71	4	15	0	4	19	1.09	.14	1.4		45.1	.86	1.37	
172	4/9	1355	4/11	0620	40	25	18	0	4	3	.94	.15	1.1		53.3	.86	1.33	
173	4/14	0605	4/14	1106	5	1	5	1	0	3	.35	.13			43.3	.25	.33	
174	4/17	0100	4/17	0323	2	23	2	23	0	3	.23	.13			40.5	.22	.16	
175	4/21	0147	4/22	2300	45	13	7	30	4	4	.38	.10			43.5	.26	.17	
175A	4/25	2020	4/26	0100	4	40	2	0	1	3	.02	T				.02	.24	
176	4/28	0400	4/29	0140	21	40	7	0	3	2	.22	.07			43.0	.18		
176A	5/10	0100	5/10	0600	5	0				11	T							
176B	7/23	1645	7/23	1655	0	10	0	10	0	74	.02	.02						
177	8/9	1935	8/10	0400	8	25	6	35	1	17	.55	.26	1.5		63.8	.46	.46	
Total											16.65					15.15	21.49	

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1942-43

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
	Storm start		Storm stop		Storm duration		Actual raining time						Wind speed			Range in precipitation		
Storm number	Date	Time	Date	Time	Hr.	Min.	Hr.	Min.	Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Storm avg.	Max. hourly	Avg. storm temp. °F.	1500 ft: IF-50	5200 ft: IF-32	Character of precipitation
											Inches	IPH	MPH			Inches		Rain unless otherwise noted
	1942																	
178	10/11	2240	10/12	0200	3	20	3	20	0	62	0.91	0.28	1.4		51.5	1.48	0.59	
179	10/28	0439	10/28	1630	11	51	11	51	0	16	.93	.24	1.5		44.2	.84	1.26	
180	11/18	2200	11/19	0730	9	30	9	30	0	21	.67	.12	1.4		49.6	.61	.74	
180A	12/4		12/5							15	T							
181	12/23	1950	12/25	0100	29	10	19	0	2	18	1.45	.28	0.9		47.5	1.41	1.24	
	1943																	
182	1/21	0900	1/23	2010	59	10	59	10	0	27	20.90	.95	7.4		45.6	15.14	25.72	
183	1/25	1639	1/27	0304	34	25	17	41	4	2	1.51	.19	1.5		45.7	1.19	1.50	
184	1/29	1651	1/31	0932	40	41	22	15	4	2	1.02	.13	1.5		46.0	1.24	1.41	
185	2/8	0115	2/8	1630	15	15	6	47	3	8	.65	.18	1.8		43.8	.66	.68	
186	2/20	2100	2/24	0700	82	0	55	30	6	12	6.45	.62	3.5		45.4	5.29	10.63	Little hail
187	3/3	0510	3/5	0600	48	50	43	26	1	7	6.94	.41	2.7		47.2	6.22	9.79	
187A	3/6		3/6							1	T					.07	.02	
187B	3/9	1300	3/10	0500	16	0	6	0	4	3	.05	.01				.06	.02	
188	3/17	1330	3/18	0530	16	0	16	0	0	7	.66	.13	1.0		45.3	.62	.66	
189	3/21	1730	3/22	0330	10	0	5	7	2	3	.18	.05			44.5	.15	.29	
190	4/5	1640	4/6	1830	25	50	18	40	2	14	1.54	.29	1.4		42.1	1.44	1.40	Hail
191	4/7	1630	4/8	1700	24	30	15	30	3	1	.78	.18	2.4		44.7	.48	.69	
191A	4/9	1140	4/9	1300	1	20	1	20	0	1	.01						.04	
192	4/11	1845	4/12	0600	11	15	0	50	1	2	.19	.14			47.3	.09	.14	
192A	4/13	1430	4/13	1530	1	0	1	0	0	1	.02	.02					.17	
193	4/15	0140	4/16	0144	24	4	4	35	3	2	.17	.02			46.7	.09	.07	
194	6/1	1510	6/3	2000	52	50	8	19	2	46	.16	.02			51.6	.04	.01	
194A	6/11	1830	6/12	1150	17	20	5	0	1	8	.04	.01					.17	
Total											45.23					37.12	57.24	

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1943-44

1 Storm number	2 Storm start Date	3 Storm start Time	4 Storm stop Date	5 Storm stop Time	6 Storm duration Hr.	6 Storm duration Min.	7 Actual raining time Hr.	7 Actual raining time Min.	8 Breaks in storm	9 Days since last rain	10 Storm total	11 Max. hrly rain rate	12 Wind speed Storm avg.	13 Wind speed Max. hourly	14 Avg. storm temp. °F.	15 Range in precipitation 1500 ft IF-50	15 Range in precipitation 5200 ft IF-32	16 Character of precipitation
											Inches	IPH	MPH			Inches		
	1943																	
195	10/17	2400	10/18	1730	17	30	12	0	3	127	1.26	0.31	2.9		47.6	1.33	1.16	All rain
195A	10/27	1230	10/27	1615	3	45	3	45	0	9	.03	.01				.01	.03	
195B	10/29	0510	10/29	0800	2	50	2	50	0	2	.03	.02				.03	.02	
196	11/17	1150	11/17	1615	4	25	4	25	0	19	.29	.08			53.3	.23	.46	
196A	11/19	0900	11/19	1600	7	0	2	0	1	2	.01	.01					.06	
196B	11/21	0145	11/21	0630	4	45	4	45	0	2	.02	.01				.02	.00	
197	12/5	0430	12/6	0503	24	33	10	0	3	14	.32	.13			39.8	.38	.49	
198	12/9	2400	12/12	1500	63	0	36	0	1	3	5.09	.38	4.0		45.4	3.75	5.32	
199	12/17	2301	12/21	1500	87	59	53	30	3	5	3.51	.50	2.2		49.6	2.69	4.65	
200	12/28	0915	12/30	2000	58	45	11	26	4	7	1.16	.21	1.9		39.5	1.19	1.37	
	1944																	
200A	1/2	1105	1/3	1230	25	25	7	15	2	3	.07	.01				.05	.06	
200B	1/4	0002	1/4	0150	1	48	1	48	0	1	.01	.01				.05	.01	
201	1/5	2120	1/6	0130	4	10	4	10	0	1	.37	.16			42.3	.38	.34	
202	1/23	1500	1/24	0130	10	30	10	30	0	17	.85	.29	3.7		42.7	.93	.73	
203	1/26	1120	1/27	1730	30	10	4	19	2	2	.16	.03			40.6	.13	.46	
203A	1/30	0600	1/30	1100	5	0	5	0	0	3	.08	.04					.10	

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1943-44 (Cont'd)

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start Date	Time	Storm stop Date	Time	Storm duration Hr.	Min.	Actual raining time Hr.	Min.	Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed Storm: avg.	Max. hourly	Avg. storm temp. °F.	Range in precipitation 1500 ft: IF-50	5200 ft: IF-32	Character of precipitation
											Inches	IPH	MPH			Inches		Rain unless otherwise noted
	1944 (Cont'd)																	
204	1/31	0515	1/31	2300	17	45	7	30	1	1	.19	.06			50.4	.21	.22	
205	2/3	1407	2/4	0200	11	53	11	53	0	3	1.24	.31	1.7		43.8	1.09	.86	
206	2/8	0845	2/8	1655	8	10	8	10	0	4	.91	.29	5.6		44.8	.77	1.21	
207	2/14	1730	2/15	0245	9	15	9	15	0	6	.47	.09			36.5	.49	.59	Snow
208	2/17	0235	2/17	1400	11	25	6	0	1	2	.18	.08			38.5	.12	.21	
209	2/19	1430	2/22	1710	74	40	66	0	3	2	11.02	.66	5.6		38.4	6.90	16.40	Snow
210	2/23	1701	2/26	1515	70	14	20	37	3	1	.72	.14	1.4		39.9	.62	.65	
211	2/29	1530	3/3	0434	61	4	44	49	6	3	2.38	.37	1.5		42.5	1.73	2.13	
212	3/4	1510	3/4	2200	6	50	6	50	0	1	.22	.07			44.2	.25	.17	
213	3/11	2300	3/13	2215	47	15	34	15	3	7	.73	.12	2.7		44.6	.76	.89	
214	4/8	1500	4/8	1740	2	40	2	40	0	26	.27	.16			43.0	.11	.16	
215	4/26	2147	4/28	1400	40	13	19	13	5	18	1.49	.32	1.8		42.0	1.46	1.56	
215A	5/30	0500	5/30	0800	3	0	3	0	0	32	.01	.01				.08	.04	
216	6/1	1400	6/2	2120	31	20	17	23	6	2	.22	.03			50.3	.08	.04	
217	6/8	1000	6/9	1100	25	0	11	0	3	6	.14	.02			52.0	.12	.10	
217A	9/30	0400	9/30	0530	1	30	1	30	0	113	.01	.01				.00	.00	
Total											33.46					25.88	40.45	

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1944-45

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start Date	Storm start Time	Storm stop Date	Storm stop Time	Storm duration Hr.	Storm duration Min.	Actual raining time Hr.	Actual raining time Min.	Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed Storm avg.	Wind speed Max. hourly	Avg. storm temp. °F.	Range in precipitation 1500 ft IF-50	Range in precipitation 5200 ft IF-32	Character of precipitation
											Inches	IPH	MPH			Inches		Rain unless otherwise noted
	1944																	
218A	10/23	1320	10/23	1330	0	10	0	10	0	23	T					0.00	0.00	
218B	10/27	1308	10/27	1510	2	2	2	2	0	4	T					.05	.03	
219	11/4	1735	11/7	0600	60	25	12	41	2	8	1.28	0.30	1.9		51.2	1.17	1.40	
220	11/9	2400	11/12	1800	66	0	35	51	3	2	8.34	.97	5.8		47.4	8.04	11.85	Hail
221	11/13	1100	11/14	1715	30	15	20	44	1	1	1.39	.19	2.1		44.8	1.50	2.13	Hail
222	12/2	0008	12/2	1800	17	52	8	3	1	18	.32	.11	0.7		44.8	.20	.22	
222A	12/22	0830	12/22	1600	7	30	7	30	0	20	.02	.02				T	.02	
223	12/27	2130	12/29	0545	32	15	10	34	1	5	1.37	.50	2.2		41.4	1.19	1.21	
	1945																	
224	1/19	0425	1/19	1815	13	50	11	50	1	21	.64	.16			39.0	.26	1.03	Hail
225	1/31	0550	2/3	0200	68	10	54	40	3	12	6.18	.53			47.3	5.31	8.01	
225A	2/15	0925	2/15	1145	2	20	2	20	0	12	.06	.04				.06		
226	2/17	1210	2/20	0330	63	20	7	0	5	2	.53	.12			46.2	.72	1.11	Snow
226A	2/24	1515	2/24	1645	1	30	1	30	0	4	.08	.07				.03	.08	
227	2/27	0910	3/5	0800	142	50	65	1	6	3	2.58	.32			37.9	2.68	3.81	Snow Tanbark

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1944-45 (Cont'd)

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start Date	Storm start Time	Storm stop Date	Storm stop Time	Storm duration Hr.	Storm duration Min.	Actual raining time Hr.	Actual raining time Min.	Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed Storm: avg.	Wind speed Max.: hourly	Avg. storm temp. °F.	Range in precipitation 1500 ft: IF-50	Range in precipitation 5200 ft: IF-32	Character of precipitation
											Inches	IPH	MPH			Inches		Rain unless otherwise noted
	1945 (Cont'd)																	
228	3/13	0735	3/15	1600	56	25	22	55	2	8	2.46	.36			44.7	2.49	2.18	
229	3/16	1530	3/17	0930	18	0	12	30	1	1	.51	.11			40.9	.58	.55	
230	3/21	0712	3/21	1830	11	18	11	18	0	4	.86	.30			39.4	.82	.83	Rain, hail, snow
231	3/22	0725	3/23	0215	18	50	15	15	1	1	.72	.13			37.8	.58	.77	Snow
232	3/25	2000	3/26	1900	23	0	13	30	1	2	.80	.17			39.7	.56	.94	Hail
232A	4/1	1820	4/2	0210	7	50				6	.06	.01				.03		
233	4/8	2100	4/9	0430	7	30	4	0	1	6	.50	.28			39.8	.51	.46	Snow
233A	4/25	1900	4/26	0300	8	0	8	0	0	16	.03	.01				.07		
233B	5/7	2300	5/9	0300	28	0	14	50	1	11	.04	.01				.03		
233C	5/12	1815	5/13	1700	22	45	22	45	0	3	.02	.01						
233D	5/31	0420	5/31	0450	0	30	0	30	0	18	.01	.01						
233E	6/5	0800	6/5	0900	1	0	1	0	0	5	.03	.03				.03		
233F	6/6	0001	6/6	0330	3	29	3	29	0	1	.01	T						
233G	6/21	1830	6/21	2359	5	29	5	29	0	15	T							
234	8/1	1335	8/1	1416	0	41	0	41	0	41	.15	.15				.10)	.55	
235	8/17	0835	8/18	1950	35	15	13	25	2	16	.57	.11				.62)		
235A	9/2	1600	9/2	1705	1	5	1	5	0	15	.09	.07				.15	.08	
Total											29.65					27.78	37.26	

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1945-46

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start Date	Storm start Time	Storm stop Date	Storm stop Time	Storm duration Hr.	Storm duration Min.	Actual raining time Hr.	Actual raining time Min.	Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed Storm avg.	Wind speed Max. hourly	Avg. storm temp. °F.	Range in precipitation 1500 ft IF-50	Range in precipitation 5200 ft IF-32	Character of precipitation
											Inches	IPH	MPH			Inches		
		1945																
236	10/6	1600	10/7	0715	15	15	5	1	1	34	0.60	0.36	3.4		66.5	0.61	0.90	Rain
237	10/8	0345	10/8	0838	4	53	1	43	1	1	.11	.07	3.5		62.0	.21	.03	Rain
238	10/29	0456	10/30	1130	30	34	20	51	3	21	.51	.05	3.5		56.5	.60	.72	Drizzles
239	11/5	1600	11/6	2200	30	0	19	55	2	6	.49	.09	3.7		48.6	.27	.58	Rain, mist
239A	11/15	1540	11/16	0300	11	20	4	30	2	9	.02	.01						Mist
239B	11/29	1255	11/29	1310	0	15	0	15	0	13	.01	.01						Rain
239C	12/4	1810	12/4	1845	0	35	0	35	0	5	.02	.02						Rain
240	12/11	1030	12/11	2310	12	40	5	45	2	7	.35	.21	3.3		41.4	.07	.32	Rain
241	12/21	0118	12/25	0500	99	42	63	41	2	10	13.00	1.13	6.4		47.6	11.43	14.72	Rain
		1946																
242	1/2	2050	1/3	0420	7	30	7	30	0	8	.41	.29	3.4		41.5	.30	.30	Rain
242A	1/4	2030	1/5	0750	11	20	11	20	0	1	.06	.01				.05	.12	Rain
243	2/3	0600	2/3	1950	13	50	11	12	1	29	2.15	.66	9.4		39.8	1.53	3.25	Rain, snow
243A	2/11	0500	2/11	0650	1	50	1	50	0	8	.01	T					.03	Rain
244	2/15	1857	2/15	2100	2	3	2	3	0	4	.23	.21	3.4		39.0	.26	.18	Rain, snow
245	3/13	0955	3/13	1930	9	35	9	35	0	26	.65	.21	7.2		41.8	.51	.70	Rain, snow, hail
246	3/18	2105	3/21	0210	53	5	34	4	4	5	1.01	.12	4.1		39.7	.85	1.60	Rain, snow
247	3/28	0510	4/2	0740	122	30	55	34	5	7	6.45	.51	5.3		44.4	5.80	8.04	Rain, snow
247A	4/6	0352	4/6	1935	15	43	1	8	2	4	.06	.04				.00	.06	Rain
248	5/9	0030	5/10	2400	47	30	25	0	2	33	.19	.02	4.0		49.2	T	.15	Rain
248A	5/20	1700	5/21	0400	11	0	11	0	0	10	.05	.02				.00	.02	Mist, very light
249	5/26	0350	5/26	2200	18	10	9	40	2	5	.10	.03	2.1		49.9	.10	.08	Rain
249A	7/18	1310	7/19	1700	27	50	2	40	1	53	.03	.02	4.8			.04		Thunder showers
250	9/29	1245	9/29	1310	0	25	0	25	0	72	.34	.30	7.1	9.0	78.0	.29	.25	Thunder showers
Total											26.85					22.92	32.05	

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1946-47

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start Date	Storm start Time	Storm stop Date	Storm stop Time	Storm duration Hr.	Storm duration Min.	Actual raining time Hr.	Actual raining time Min.	Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed Storm avg.	Wind speed Max. hourly	Avg. storm temp. °F	Range in precipitation 1500 ft IF-50	Range in precipitation 5200 Ft IF-32	Character of precipitation
											Inches	IPH	MPH			Inches		
	1946																	
251	9/30	1925	10/1	1500	19	35	19	35	0	1	1.62	0.32	5.7	9.1	60.2	1.15	2.93	Rain, drizzles
252	10/3	1235	10/4	0500	16	25	9	15	1	2	.62	.37	7.0	9.2	41.5	1.07	.86	Rain, hail, electric
253	10/16	0020	10/16	0540	5	20	5	20	0	12	.32	.14	5.2	7.2	47.7	.20	1.53	Rain
254	10/26	2120	10/28	1855	45	35	38	10	3	10	.98	.13	4.1		51.0	.70		Rain
254A	11/7	2120	11/8	0440	7	20	7	20	0	10	.05	.01				.12		Rain
255	11/10	2120	11/14	0930	84	10	71	10	3	2	5.98	.38	6.2	12.1	42.1	5.06	8.00	Rain
256	11/19	2030	11/20	1510	18	40	18	40	0	5	4.40	.52	6.6	12.8	46.4	3.50	6.50	Rain
257	11/23	0100	11/23	1700	16	0	16	0	0	3	1.74	.40	2.9	4.5	51.5	1.64	2.20	Rain
258	12/5	1610	12/6	1840	26	30	12	20	2	12	.48	.16	4.3	6.6	46.8	.66	8.04	Rain
259	12/23	1320	12/27	1830	101	10	75	10	3	17	5.40	.39	4.5	9.3	49.2	4.21		Rain
	1947																	
259A	1/12	2120	1/12	2400	2	40	2	40	0	16	.01	T				T		
260	1/28	0010	1/28	1733	17	23	17	23	0	16	1.47	.42	7.0	11.1	40.2	1.06	1.67	Rain
261	2/9	1045	2/9	1900	8	15	8	15	0	12	.48	.21	4.6	7.1	47.6	.53	1.92	Rain
262	2/16	2255	2/18	1545	40	50	9	51	3	7	1.07	.60	4.9	6.6	42.6	.27		Snow, sleet
262A	2/27	1500	2/27	1820	3	20	3	20	0	9	.01	T				.02		Rain
263	3/3	1745	3/5	1330	43	45	14	15	2	4	.45	.22	3.8	5.2	43.4	.51	.46	Rain
263A	3/18	1100	3/19	0010	13	10	13	10	0	13	.09	.01				.39		Rain
264	3/20	1320	3/23	0810	66	50	22	0	5	1	.70	.38	4.9	7.2	48.0	.36	1.54	Drizzles
265	3/27	1610	3/28	1220	20	10	20	10	0	4	.73	.11	4.1	7.6	50.9	.70		Rain
265A	4/3	1545	4/3	1600	0	15	0	15	0	6	.02	.02				.21		Rain
266	4/20	2210	4/22	0500	30	50	11	50	1	17	.29	.12	3.3	3.6	49.2	.16	.38	Rain
266A	5/10	1020	5/10	1100	0	40	0	40	0	18	.03	.03				.03		Rain
267	5/13	2140	5/15	0200	28	20	15	20	2	3	.16	.04			49.4	.10	.30	Rain
268	5/26	1550	5/27	1630	24	40	17	0	2	11	.13	.03			50.3	.10		Rain
268A	5/29	2230	5/30	0650	8	20	8	20	0	2	.07	.02				.05		Rain
268B	6/19	2340	6/20	2050	21	10	15	20	1	20	.06	.01				.06		Rain
268C	8/8	0645	8/8	0935	2	50	0	50	1	49	.05	.04				T		Rain
269	9/17	0550	9/17	2030	14	40	14	40	0	40	.27	.05			57.4	.15		Rain
Total											27.68					23.01	36.33	

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1947-48

1 Storm number	2 Storm start: Date	3 Storm start: Time	4 Storm stop: Date	5 Storm stop: Time	6 Storm duration: Hr.	Storm duration: Min.	7 Actual raining time: Hr.	Actual raining time: Min.	8 Breaks in storm	9 Days since last rain	10 Storm total	11 Max. hrly rain rate	12 Wind speed: Storm avg.	13 Wind speed: Max. hourly	14 Avg. storm temp. °F.	15 Range in precipitation: 1500 ft: IF-50	Range in precipitation: 5200 ft: IF-32	16 Character of precipitation
											Inches	IPH	MPH			Inches		
	1947																	
269A	11/1		11/1							45	T							
270	11/9	1332	11/9	1400	0	28	0	28	0	8	0.08	0.08			52.0	0.08	0.07	Rain
270A	11/15	1840	11/15	1845	0	5	0	5	0	6	T							
271	12/1	0930	12/2	0140	16	10	16	10	0	16	.16	.08	3.8	5.7	44.2	.16	.31	Rain
272	12/4	0230	12/5	1750	39	20	26	32	2	2	2.90	.39	4.8	11.3	40.8	2.12	3.08	Rain, hail, snow
272A	12/20	1630	12/20	1740	1	10	1	10	0	15	.04	.04				.04	.05	Rain
	1948																	
272B	1/25	2310	1/26	0550	6	40	6	40	0	36	.04	.03				.02	.06	Rain
273	2/1	2150	2/2	0420	6	30	6	30	0	6	.16	.06			39.0	.08	.11	Rain
274	2/4	2200	2/6	1550	41	50	30	30	3	2	3.62	.49	7.0	16.9	36.0	2.88	4.76	Rain, snow
275	2/28	0720	2/28	1815	10	55	8	45	1	22	.24	.07	2.4	5.7	38.8	.38	.47	Rain
275A	3/8	2110	3/9	0030	3	20	3	20	0	9	.01	.01					.03	Rain
276	3/13	1610	3/14	2230	30	20	23	20	1	4	1.98	.39	4.1	9.3	38.2	1.93	2.28	Rain, snow, hail
277	3/16	2040	3/17	1650	20	10	10	43	1	2	.67	.14	3.4	6.5	39.6	.60	.73	Rain, hail, snow
278	3/19	0810	3/20	0120	17	10	14	0	1	2	.34	.15	2.9	5.9	37.0	.41	.45	Rain
279	3/24	0950	3/25	0140	15	50	8	30	1	4	.98	.44	8.0	10.0	36.2	.97	1.34	Rain, hail
279A	3/29	0720	3/29	0850	1	30	1	30	0	4	.03	.02					.06	Rain
280	4/2	0540	4/3	1400	32	20	26	50	2	4	1.57	.33	4.5	13.7	43.6	1.01	1.82	Rain
281	4/5	1830	4/6	0320	8	50	8	50	0	2	.35	.10	3.1	5.9	38.6	.59	.34	Rain
282	4/10	0710	4/10	1310	6	0	6	0	0	4	.15	.05	3.4	4.8	48.0	.20	.18	Rain
283	4/28	1620	4/28	2230	6	10	6	10	0	18	1.65	.49	14.2	18.0	45.7	.80	2.50	Thunder showers
283A	5/18	1310	5/18	2200	8	50	0	20	1	20	.05	.04				T	.10	Rain
283B	5/27	1530	5/28	0500	13	30	13	30	0	9	.02	.01					.05	Rain
283C	5/30	1100	5/30	1400	3	0	3	0	0	2	.06	.04				.09	.20	Rain
284	5/31	2330	6/2	1110	35	40	19	30	4	1	.73	.45	3.5	6.5	50.3	.31	.52	Rain
Total											15.83					12.67	19.51	

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1948-49

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start		Storm stop		Storm duration		Actual raining time		Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed		Avg. storm temp. °F.	Range in precipitation		Character of precipitation
	Date	Time	Date	Time	Hr.	Min.	Hr.	Min.					Storm avg.	Max. hourly		1500 ft IF-50	5200 ft IF-32	
											Inches	IPH	MPH			Inches		
	1948																	
285	10/17	1050	10/18	1020	23	30	10	40	2	137	0.43	0.11	4.3	10.8	57.8	0.36	0.60	Rain
286	10/29	1430	10/30	0800	17	30	4	40	2	11	.11	.03	2.4	3.1	44.8	.16	.10	Rain
286A	11/3	1410	11/3	1500	0	50	0	50	0	4	T	T						Rain
287	12/3	1640	12/3	2400	7	20	2	20	1	30	.54	.43	8.3	12.8	36.2	.52	.72	Rain
288	12/16	2030	12/17	1650	20	20	13	30	2	13	1.78	.30	4.4	8.2	37.0	1.88	2.18	Rain
289	12/22	0610	12/23	0150	19	40	10	20	1	5	.40	.12	2.6	4.6	38.7	.37	.47	Rain
290	12/26	1540	12/27	1430	22	50	13	20	2	3	1.24	.22	4.8	10.2	40.5	1.18	1.67	Rain
	1949																	
291	1/8	2330	1/14	1240	133	10	55	40	8	12	1.40	.15	3.4	11.5	31.0	1.58	3.18	Hail, snow
292	1/19	0950	1/21	0300	41	10	32	35	1	5	2.28	.19	3.0	5.4	38.3	2.20	2.25	Snow, rain
293	1/22	0820	1/24	0140	41	20	20	40	3	1	.99	.16	2.7	7.4	29.9	.84	.95	Snow, rain
294	2/3	0830	2/3	1930	11	0	3	40	1	10	.31	.10	1.8	2.5	34.7	.36	.30	Snow
295	2/7	0538	2/7	1710	11	32	11	32	0	4	.44	.16	2.3	3.9	34.3	.42	.47	Snow
296	2/11	1410	2/11	1905	4	55	4	55	0	4	.65	.19	6.5	8.7	37.7	.74	.60	Rain
297	2/24	0615	2/25	0310	20	55	13	50	2	13	.93	.18	4.7	8.2	40.4	.83	1.06	Rain
298	2/26	1440	2/28	0200	35	20	21	50	2	1	1.19	.22	3.3	7.8	37.1	.90	.83	Rain
298A	3/2	1150	3/3	0340	15	50	10	20	1	2	.08	.02				.08	.17	Rain
299	3/4	1520	3/4	2100	5	40	5	40	0	1	.71	.20	2.2	2.5	39.2	.53	.42	Rain
300	3/7	0615	3/7	1130	5	15	0	55	1	3	.11	.09	4.2	6.3	39.2	.16	.09	Rain
301	3/10	2105	3/11	0430	7	25	7	25	0	3	.66	.16	5.8	6.3	41.5	.73	.79	Rain
302	3/19	1350	3/20	0200	12	10	12	10	0	8	.36	.14	3.8	5.7	42.0	.42	.45	Rain
303	3/22	1750	3/24	1330	43	40	3	30	3	2	.27	.11	5.7	9.3	37.2	.07	.29	Rain, hail
303A	3/28	0450	3/28	0610	1	20	1	20	0	4	.04	.03				.10	.01	Rain
304	3/30	1700	3/31	0200	9	0	4	45	1	2	.14	.04	4.9	7.2	33.2	.01	.15	Rain, snow
304A	4/1	1800	4/2	0640	12	40	1	55	1	1	.02	.02				.07	.08	Rain
304B	4/14	2310	4/15	0400	4	50	4	50	0	12	.02	.01				.01	.01	Rain
304C	4/17	0109	4/17	0220	1	11	1	11	0	2	.02	.02				.02		Light rain
304D	4/18	1423	4/19	0630	16	7	16	7	0	1	.03	T				.02	.02	Rain, mist
305	5/13	1630	5/19	1300	140	30	82	25	9	24	1.79	.08	3.5	7.2	45.0	1.39	1.70	Showers
Total											16.94					15.95	19.56	

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1949-50

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start Date	Storm start Time	Storm stop Date	Storm stop Time	Storm duration Hr.	Storm duration Min.	Actual raining time Hr.	Actual raining time Min.	Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed Storm avg.	Wind speed Max. hourly	Avg. storm temp. °F.	Range in precipitation 1500 ft IF-50	Range in precipitation 5200 ft IF-32	Character of precipitation
											Inches	IPH	MPH			Inches		
	1949																	
305A	10/7	1355	10/7	1450	0	55	0	55	0	141	0.01	0.01				0.01	0.03	Light rain
306	10/15	1710	10/19	0250	81	40	8	22	4	8	.17	.04			49.0	.17	.21	Rain, sleet, snow
306A	11/8	0530	11/8	0710	1	40	1	40	0	20	.05	.05				.03	.02	Rain
307	11/9	1420	11/10	1430	24	10	24	10	0	1	3.87	.51	6.7	14.8	57.2	3.09	4.71	Rain, snow, hail
308	12/7	2125	12/10	0310	53	45	13	5	3	27	.54	.14			48.2	.42	.62	Rain, light snow
309	12/17	1415	12/19	1515	49	0	39	55	2	7	5.42	.54	3.9	8.7	45.2	5.19	6.42	Rain, snow
	1950																	
310	1/2	1645	1/2	2030	3	45	3	45	0	14	.15	.09	3.7	6.5	40.5	.10	.27	Rain, snow
311	1/8	0845	1/8	2050	12	5	12	5	0	6	1.56	.55	5.1	11.1	42.0	1.23	1.64	Rain, snow
312	1/11	0925	1/12	1225	27	0	11	15	2	3	1.11	.25	3.5	8.5	35.0	1.07	1.11	Rain, snow
313	1/14	1340	1/14	1625	2	45	2	45	0	2	.10	.04	2.3	3.3	42.5	.12	.19	Rain
314	1/28	1425	1/29	1020	19	55	17	50	1	14	.64	.08	2.0	2.4	38.1	.65	.75	Rain
315	2/5	0725	2/6	2355	40	30	27	15	2	7	2.56	.63	2.8	6.1	47.4	2.50	2.92	Rain
316	2/10	0305	2/11	0310	24	5	20	45	1	4	.50	.09	3.0	6.3	45.9	.44	.59	Rain
316A	3/2	0010	3/2	0250	2	40				19	T							
317	3/24	1535	3/25	0250	11	15	11	15	0	22	1.74	.49	5.3	9.8	39.6	1.90	2.15	Rain, snow
318	4/8	0320	4/9	0440	25	20	15	20	3	14	1.87	.35	6.1	13.9	40.8	1.39	2.25	Rain, hail, snow
318A	4/22	1645	4/24	0200	33	15	16	45	1	13	.06	.01	3.4	4.6		.00	.00	Drizzles
319	4/27	1605	4/28	2330	31	25	12	50	1	3	.10	.04			46.6	.06	.07	Light rain

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1949-50 (Cont'd)

1 Storm number	2 Storm start	3	4 Storm stop	5	6 Storm duration		7 Actual raining time		8 Breaks in storm	9 Days since last rain	10 Storm total	11 Max. hrly. rain rate	12 Wind speed	13	14 Avg. storm temp. °F.	15 Range in precipitation		16 Character of precipitation
	Date	Time	Date	Time	Hr.	Min.	Hr.	Min.					Storm avg.	Max. hourly		1500 ft: IF-50	5200 ft: IF-32	
											Inches	IPH	MPH			Inches		
	1950 (Cont'd)																	
319A	5/1	0140	5/1	0550						3	T					.02	T	Drizzle
319B	5/2	2140	5/3	2230	24	50	2	10	3	1	.07	.05	3.1	3.5		.03	.08	Light rain
320	5/16	2210	5/17	1930	21	20	19	20	1	13	.12	.01	3.0	4.0	46.4	.05	.03	Light rain
320A	5/23	0030	5/23	0540	5	10	5	10	0	6	.02	.01				.00	.01	Light rain
320B	6/6	0615	6/6	1420	8	5	8	5	0	14	.08	.02	4.4	5.2		.02	.01	Light rain
320C	6/24	0225	6/24	0640						18	T					.00		
320D	7/9	0135	7/9	0145						15	T							
320E	7/24	0525	7/24	0615						15	T							
320F	9/3		9/3							41	T							
320G	9/4		9/4							1	T							
320H	9/5		9/5							1	T							
320I	9/6	1435	9/6	1440	0	5	0	5	0	1	.04	.04				.04	.00	Shower
Total											20.78					18.53	24.08	

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1950-51

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start Date	Storm start Time	Storm stop Date	Storm stop Time	Storm duration Hr.	Storm duration Min.	Actual raining time Hr.	Actual raining time Min.	Breaks in storm	Days since last rain	Storm total	Max. hrly. rain rate	Wind speed Storm avg.	Wind speed Max. hourly	Avg. storm temp. °F.	Range in precipitation 1500 ft IF-50	Range in precipitation 5200 ft IF-32	Character of precipitation
											Inches	IPH	MPH			Inches		
	1950																	
321	10/26	1900	10/27	0525	10	25	10	25	0	50	0.26	0.06		2.7	55.0	0.19	0.20	Rain
321A	10/31	0015	10/31	0040	0	25	0	25	0	4	.02	.02				.00	.01	Rain
322	11/13	1040	11/15	0820	45	40	12	0	3	13	1.25	.53	2.2	3.4	42.4	.98	1.60	Rain, hail, snow
323	11/18	1200	11/19	2335	35	35	17	33	3	3	.32	.08	2.3	4.4	54.5	.42	.42	Light rain
	1951																	
323A	1/4	1900	1/4	1930	0	30	0	30	0	46	.02	.02				.03	.04	Shower
324	1/10	1035	1/10	1225	1	50	1	50	0	6	.34	.25	5.0	7.2	41.8	.35	.35	Rain, snow
325	1/11	1220	1/11	1730	5	10	5	10	0	1	1.20	.80	6.6	8.9	37.3	1.48	1.27	Rain, hail, snow
326	1/16	0525	1/16	0735	2	10	2	10	0	5	.17	.11	3.9	5.7	35.5	.15	.20	Rain
327	1/18	1855	1/19	0625	11	30	11	30	0	2	.64	.13	2.3	5.2	45.3	.91	.54	Rain
328	1/27	2010	1/30	0345	55	35	31	32	4	8	1.46	.36	4.1	6.7	44.4	1.22	1.42	Rain, light snow
329	2/11	1910	2/12	0145	6	35	6	35	0	12	.14	.05	3.9	7.2	46.2	.22	.12	Rain
330	2/22	1655	2/24	0220	33	25	5	5	3	10	.27	.12	3.1	4.8	34.0	.28	.59	Rain, snow
330A	2/25		2/25							1	T							Drizzles
331	2/26	1830	2/27	0410	9	40	9	40	0	1	.84	.28	3.1	5.4	33.9	.72	1.10	Rain, snow
332	3/1	0050	3/1	2355	23	5	17	35	1	2	.84	.20	2.5	5.0	33.4	.73	1.36	Rain, snow
332A	3/27	0110	3/27	0700						26	T					.00		

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1950-51 (Cont'd)

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start		Storm stop		Storm duration		Actual raining time		Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed		Avg. storm temp. °F.	Range in precipitation		Character of precipitation
	Date	Time	Date	Time	Hr.	Min.	Hr.	Min.					Storm avg.	Max. hourly		1500 ft: IF-50	5200 ft: IF-32	
											Inches	IPH	MPH			Inches		
	1951 (Cont'd)																	
332B	3/29	2235	3/30	0300	4	25	4	25	0	2	.04	.01	3.9	5.4		.01	.01	Rain
333	4/3	1925	4/6	2240	75	15	37	0	4	4	.86	.25	2.5	6.5	47.6	.63	.59	Rain
333A	4/15		4/16								T					.02	.00	Drizzles
333B	4/18	2030	4/21	0410	55	40	15	0	2	12	.05	T	2.3	2.9		.00	.25	Light rain
334	4/25	0420	4/25	1555	11	45	11	45	0	4	1.00	.30	5.9	9.8	45.6	.83	1.14	Rain
335	4/28	1640	4/29	1805	25	25	14	5	1	3	1.58	.56	7.7	12.4	42.6	1.66	2.30	Rain, hail
335A	5/11	0410	5/11	0500	0	50	0	50	0	12	T					.00	.00	Light rain
336	5/13	2215	5/14	0620	8	5	3	25	1	2	.14	.09	2.5	4.2	38.8	.16	.16	Rain
336A	6/5	0030	6/5	0500						22	T							
336B	6/8	0030	6/8	0400						3	T							
336C	7/28		7/28							50	T							
336D	8/29	0730	8/29	0900						32	T							
336E	9/28	0020	9/28	0235	2	15	2	15	0	30	.03	.02				.03	.15	Light rain
Total											11.47					11.02	13.82	

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1951-52

1 Storm number	2 Storm Start Date	3 Storm Start Time	4 Storm Stop Date	5 Storm Stop Time	6 Strom duration Hr.	6 Strom duration Min.	7 Actual raining time Hr.	7 Actual raining time Min.	8 Breaks in storm	9 Days since last rain	10 Storm total	11 Max. hrly rain rate	12 Wind speed Storm avg.	13 Wind speed Max. hourly	14 Avg. storm temp. °F.	15 Range in precipitation 1500 ft IF-50	15 Range in precipitation 5200 ft IF-32	16 Character of precipitation
											Inches	IPH	MPH			INCHES		
	1951																	
337	10/24	2130	10/25	1930	22	0	8	10	1	26	1.80	0.42	8.1	14.5	48.2	1.35	2.10	Rain
337A	10/29	2050	10/30	0200	5	10	5	10	0	4	.01	.01						Light rain
338	11/19	1450	11/23	1800	99	10	62	7	6	20	2.73	.40	5.5	10.0	43.3	2.51	3.69	Rain, snow
339	12/1	1740	12/2	0300	9	20	9	20	0	8	.50	.13	1.8	3.3	49.3	.65	.40	Rain
339A	12/3	1610	12/4	0200	9	50	9	50	0	1	.01	.01					.03	Rain
340	12/4	1815	12/5	0250	8	35	8	35	0	1	2.22	.63	3.7	7.8	46.0	1.61	2.16	Rain
341	12/11	1850	12/12	1500	20	10	15	22	1	6	1.82	.28	5.4	10.0	46.6	1.60	1.86	Rain, snow
342	12/19	0120	12/19	0900	7	40	7	40	0	7	.58	.20	3.0	6.3	41.1	.38	.53	Rain
343	12/28	0844	12/30	1920	58	36	50	51	2	9	5.92	.43	3.4	9.1	47.3	6.26	6.20	Rain, snow
	1952																	
344	1/6	2240	1/8	0700	32	20	6	50	1	7	.56	.17	5.4	9.8	36.2	.47	.77	Rain, snow
345	1/12	1250	1/13	1050	22	0	22	0	0	4	3.43	.56	7.0	14.4	40.1	2.37	4.09	Rain, snow
346	1/15	0325	1/18	1350	82	25	56	52	2	2	7.54	.62	5.0	11.9	41.6	6.55	8.93	Rain, snow
347	1/24	2100	1/25	1330	16	30	16	30	0	6	.86	.12	2.4	4.6	44.2	.76	.92	Rain
347A	2/9	1650	2/9	1720	0	30	0	30		15	T					.05	.02	Rain
347B	2/11	1440	2/11	2000	5	20	5	20	0	2	.02	.01				.13	.02	Rain

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1951-52 (Cont'd)

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm Start Date	Storm Start Time	Storm Stop Date	Storm Stop Time	Storm duration Hr.	Storm duration Min.	Actual raining time Hr.	Actual raining time Min.	Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed Storm avg.	Wind speed Max. hourly	Avg. storm temp. °F.	Range in precipitation 1500 ft IP-50	Range in precipitation 5200 ft IP-52	Character of precipitation
											Inches	IPH	MPH			INCHES		
	1952 (Cont'd)																	
347C	2/17	2100	2/17	2130	0	30	0	30	0	6	.09	.09				.02	.10	Rain
347D	2/23	1750	2/24	0200	8	10	8	10		6	T	.01						Rain
348	2/29	0850	3/1	1705	32	15	18	9	3	5	1.56	.25	5.0	9.8	41.1	.99	1.62	Rain, snow
349	3/6	2210	3/8	1800	43	50	22	20	1	5	3.22	.30	3.2	7.8	35.2	3.86	3.98	Rain, snow
350	3/10	0700	3/11	0400	21	0	21	0	0	2	1.02	.19	6.3	11.7	37.8	.84	1.26	Rain, snow
351	3/12	1440	3/13	2000	29	20	10	20	2	1	.52	.13	2.6	6.1	34.3	.41	.50	Rain, snow
352	3/14	1500	3/16	1500	48	0	34	20	2	1	3.29	.36	4.8	17.3	36.9	3.10	5.99	Rain, snow
353	4/7	1240	4/8	0300	14	20	14	20	0	22	.98	.30	6.3	8.5	45.7	1.02	1.87	Rain
354	4/10	0820	4/11	0250	18	30	13	56	1	2	.36	.11	4.1	7.8	41.4	.28	.50	Rain
355	4/19	0600	4/20	0600	24	0	19	21	2	8	.28	.07			44.4	.76	.38	Rain
356	4/25	0010	4/29	0620	102	10	39	12	7	5	1.16	.23	4.1	8.9	44.3	.71	1.24	Rain
356A	6/26	0030	6/26	0140	1	10	1	10	0	58	.03	.02						Rain
356B	7/27	1500	7/27	1520	0	20	0	20	0	31	.03	.03						Rain
356C	8/28	0830	8/28	0835	0	5	0	5	0	32	.02	.02						Rain
357	9/19	0530	9/20	0240	21	10	10	30	2	22	.46	.09	5.1	8.9	64.8	.35	.57	Rain
357A	9/25	0852	9/25	0910	0	18	0	18	0	5	.05	.05				.00	.03	Rain
357B	9/26	1156	9/26	1220	0	24	0	24	0	1	.03	.03				.00	.02	Rain
Total											41.10					37.03	49.78	

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1952-53

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm Number	Storm start		Storm stop		Storm duration		Actual raining time		Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed		Avg. storm temp. °F.	Range in precipitation		Character of precipitation
	Date	Time	Date	Time	Hr.	Min.	Hr.	Min.					Storm avg.	Max. hourly		1500 ft IF-50	5200 ft IF-32	
											Inches	IPH	MPH			Inches		
	1952																	
358	11/7	2030	11/8	0520	8	50	8	50	0	42	0.65	0.27	4.3	8.5	47.6	0.77	0.76	Rain
359	11/14	0920	11/16	0200	40	40	22	27	3	6	2.84	.49	4.6	11.5	37.4	2.72	3.77	Rain, snow, hail
360	11/22	1820	11/22	2400	5	40	5	40	0	6	.29	.13	7.2	11.1	35.0	.51	.55	Rain, snow
361	11/29	2230	11/30	1540	17	10	5	40	1	7	.72	.37	3.5	6.5	40.8	.58	.74	Rain, snow
362	12/1	1300	12/1	2230	9	30	9	30	0	1	1.71	.67	6.2	13.2	44.4	1.34	2.26	Rain, snow
363	12/5	2240	12/6	0200	3	20	3	20	0	4	.10	.05	1.6	1.8	42.2	.07	.10	Rain
363A	12/17	1230	12/17	1600	3	30	3	30	0	11	.02	T	3.3	3.3		.06	.18	
364	12/19	2000	12/20	1520	19	20	13	37	1	2	1.16	.26	4.5	8.0	41.7	1.01	1.60	Rain, snow
365	12/27	1914	12/28	0640	11	26	6	31	1	7	.66	.24	3.1	6.3	38.5	.61	.96	Rain, snow
366	12/30	1450	12/31	0300	12	10	10	3	1	2	.79	.37	5.7	8.9	34.8	.72	.92	Rain, snow
	1953																	
367	1/6	0640	1/7	0750	25	10	25	10	0	6	1.17	.18	2.4	4.6	44.6	1.20	1.19	Rain
367A	1/8	0830	1/8	1057	2	27	2	27	0	1	.02	.01				.03	.07	Rain
368	1/13	1047	1/13	2000	9	13	9	13	0	5	.43	.11	2.5	4.4	48.2	.44	.39	Rain
369	2/23	0420	2/23	2210	17	50	13	26	2	41	.64	.14	2.8	5.7	32.6	.70	1.13	Rain, snow, hail
370	2/28	2130	3/1	2130	24	0	9	55	2	5	.67	.17	4.4	9.1	35.0	.73	1.04	Rain, snow
371	3/19	1850	3/20	0350	9	0	9	0	0	18	1.36	.25	5.4	8.2	45.0	1.75	1.07	Rain

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1952-53 (Cont'd)

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
	Storm start		Storm stop		Storm duration		Actual raining time		Breaks in stem	Days since last rain	Storm total	Max. hrly. rain rate	Wind speed		Avg. storm temp. °F.	Range in precipitation		Character of precipitation
Storm Number	Date	Time	Date	Time	Hr.	Min.	Hr.	Min.					storm avg.	Max. hourly		1500 ft IP-50	5200 ft IP-52	
											Inches	IPH	MPH			Inches		
	1953 (Cont'd)																	
371A	3/28	1948	3/28	2400	4	12	4	12	0	8	.10	.05	6.1	6.7		.02	.08	Rain
371B	4/5	1930	4/6	2330	28	0	12	0	1	8	.09	.01	2.6	3.9		.07	.06	Rain
372	4/19	2325	4/21	0610	30	45	14	55	3	13	.76	.15	4.4	8.9	46.3	.58	1.10	Rain
373	4/27	0750	4/28	0200	18	10	15	41	1	6	.93	.23	2.9	5.2	48.8	.88	.87	Rain
373A	4/29	1044	4/30	1730	30	46	1	45	1	1	.02	.01				.11	.03	Rain
373B	5/15	0100	5/15	2400	23	0	5	40	2	15	.03	.01				T	.11	Rain
374	5/27	1607	5/28	0830	16	23	8	23	1	12	.16	.07	4.2	7.0	42.6	.16	.31	Rain
374A	6/1	0320	6/1	0610	2	50	2	50	0	4	T	T				.01	.00	Rain
374B	6/6	2120	6/7	0240	5	20	5	20	0	5	T	T				T	.00	Rain
374C	6/18	0150	6/19	0200	24	10	20	10	1	11	.08	.02				T	.08	Rain, mist
374D	7/12	1350	7/12	1430	0	40	0	40	0	23	T	T				T	T	Rain
374E	8/11	1655	8/11	1710	0	15	0	15	0	30	.07	.07				T	.07	Rain
Total											15.47					15.07	19.44	

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1953-54

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start		Storm stop		Storm duration		Actual raining time		Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed		Avg. storm temp. °F.	Range in precipitation		Character of precipitation
	Date	Time	Date	Time	Hr.	Min.	Hr.	Min.					Storm avg.	Max. hourly		1500 ft IF-50	5200 ft IF-32	
											Inches	IPH	MPH			Inches		
	1953																	
374F	10/18	2000	10/18	2130	1	30	1	30	0	68	T					T		Rain
375	10/22	1545	10/22	2200	6	15	6	15	0	4	0.19	0.12	5.3	5.9	41.8	0.33	0.86	Rain, snow
375A	11/2		11/2							11	T							Rain
376	11/4	2320	11/5	0540	6	20	6	20	0	2	.20	.05	4.8	7.6	44.9	.10	.17	Rain
377	11/14	0645	11/14	1900	12	15	10	15	1	9	1.05	.43	3.3	5.0	50.6	.89	1.59	Rain
377A	11/20	0240	11/20	0400	1	20	1	20	0	6	.07	.05	4.6	5.7		.11	.10	Rain, snow
378	12/4	0230	12/4	0700	4	30	4	30	0	14	.41	.20	2.5	3.7	43.5	.58	.44	Rain
	1954																	
379	1/11	1620	1/12	2330	31	10	10	30	4	38	.78	.32	3.9	8.0	35.3	.95	1.43	Rain, snow
380	1/17	2030	1/20	0350	55	20	52	0	1	5	6.56	.57	5.2	13.7	45.1	4.86	8.17	Rain
381	1/23	2140	1/25	1050	37	10	32	50	1	3	4.76	.50	6.6	16.5	43.8	4.98	5.49	Rain, snow
382	2/13	0640	2/14	1655	34	15	24	7	4	19	4.24	.67	5.4	12.6	48.6	3.84	4.68	Rain,snow,hail,sleet
382A	2/17	2040	2/18	0120	4	40	4	40	0	3	.09	.04			44.5	.16	.09	Rain
382B	3/8		3/8							18	T							Rain

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1953-54 (Cont'd)

1 Storm number	2 Storm start Date	3 Time	4 Storm stop Date	5 Time	6 Storm duration Hr.	 Min.	7 Actual raining time Hr.	 Min.	8 Breaks in storm	9 Days since last rain	10 Storm total	11 Max. hrly rain rate	12 Wind speed Storm avg.	13 Max. hourly	14 Avg. storm temp. °F.	15 Range in precipitation 1500 ft: IP-50	 5200 ft: IP-32	16 Character of precipitation
											Inches	IPH	MPH			Inches		
	1954 (Cont'd)																	
382C	3/10	2000	3/10	2200	2	0	2	0	0	2	T					.02		Rain
383	3/16	1620	3/17	0650	14	30	14	30	0	6	1.30	.45	7.9	17.3	35.0	1.12	1.60	Rain, snow, sleet
384	3/19	2200	3/25	1500	137	0	79	58	9	2	3.65	.18	3.7	10.2	41.1	2.78	4.60	Rain, snow, hail
385	3/29	1610	3/30	0425	12	15	12	15	0	4	1.40	.22	4.3	10.0	41.3	1.20	1.56	Rain, snow
386	4/27	1620	4/28	0510	12	50	12	50	0	28	.21	.04	3.1	5.0	46.2	.23	.22	Rain
386A	4/29	1700	4/30	0200	9	0	9	0	0	1	.01	T	3.0	3.7		.02	.03	Rain
386B	5/9	0220	5/9	0500	2	40	2	40	0	9	T							Rain
386C	5/16		5/16							7	T					.00		Rain
386D	5/29	1900	5/29	2200						13	T							Rain
386E	6/16	0020	6/16	0600						18	T					.01		Rain
386F	6/17	0001	6/17	0600						1	T							Rain
386G	6/25		6/25							8	T					T		Rain
386H	6/26		6/26							1	T					T		Rain
386I	6/26		6/27							1	T					T		Rain
386J	7/12		7/13							15	T							Rain
386K	7/25		7/25							12	T					.02		Rain
386L	8/3		8/3							9	T							Rain
386M	9/1		9/1							29	T							Rain
386N	9/29	0100	9/29	0720						28	T							Rain
Total											24.92					22.20	31.03	

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1954-55

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start Date	Storm start Time	Storm stop Date	Storm stop Time	Storm duration Hr.	Storm duration Min.	Actual raining time Hr.	Actual raining time Min.	Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed Storm avg.	Wind speed Max. hourly	Avg. storm temp. °F.	Range in precipitation 1500 ft IF-50	Range in precipitation 5200 ft IF-32	Character of precipitation
											Inches	IPH	MPH			Inches		
	1954																	
387	11/10	2032	11/12	0400	31	28	19	51	3	42	2.68	0.67	4.5	10.6	51.7	2.31	3.16	Rain
388	11/15	1910	11/16	0400	8	50	8	50	0	3	.20	.10	2.9	3.7	45.1	.21	.33	Rain
389	11/28	2400	11/29	1040	10	40	10	40	0	12	.20	.07	2.9	6.3	44.6	.12	.06	Rain
390	12/3	0210	12/4	1440	36	30	20	30	2	4	1.35	.35	4.2	9.1	51.0	1.03	1.60	Rain
391	12/9	1350	12/10	0300	13	10	11	10	1	5	.62	.22	4.3	7.0	42.9	.66	.88	Rain
391A	12/15	0040	12/15	0257	2	17	2	17	0	5	T							Rain
	1955																	
392	1/1	1000	1/2	0400	18	0	18	0	0	17	1.14	.30	3.7	7.6	46.0	.85	1.52	Rain,snow,sleet
392A	1/3	1140	1/3	1300	1	20	1	20	0	1	.03	.02					.05	Rain
393	1/6	0620	1/6	2400	17	40	17	40	0	3	.60	.16	4.5	7.4	35.6	.47	1.10	Rain, snow
394	1/9	2320	1/10	2300	23	40	17	40	1	3	1.91	.42	3.4	6.3	34.5	1.80	2.40	Rain, snow
395	1/15	2140	1/16	1440	17	0	17	0	0	5	1.27	.19	2.9	5.4	37.3	1.26	1.22	Rain, snow
396	1/18	0740	1/19	0200	18	20	18	20	0	2	1.95	.35	4.8	12.2	33.4	1.56	2.39	Rain, snow, hail
397	1/30	1835	1/31	0650	12	15	9	35	1	11	.25	.18	5.4	6.1	38.4	.21	.26	Rain, snow
398	2/16	1220	2/17	2400	35	40	21	56	2	16	.74	.12	2.8	6.1	50.6	.66	1.01	Rain
399	2/25	2300	2/27	2300	48	0	31	32	2	8	1.50	.23	4.3	7.8	39.7	.87	1.85	Rain, snow
400	3/10	1238	3/11	0120	12	42	12	42	0	11	.98	.31	3.2	5.7	48.1	.70	.70	Rain
400A	3/14		3/14							3	T	T				.07.	.03	Rain
400B	3/16		3/16							2	T	T					.04	Rain, sleet
400C	4/1		4/1							16	T	T					.01	Rain

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1954-55 (Cont'd)

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start Date	Storm start Time	Storm stop Date	Storm stop Time	Storm duration Hr.	Storm duration Min.	Actual raining time Hr.	Actual raining time Min.	Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed Storm avg.	Wind speed Max. hourly	Avg. storm temp. °F.	Range in precipitation 1500 ft IP-50	Range in precipitation 5200 ft IP-52	Character of precipitation
											Inches	IPH	MPH			Inches		
	1955 (Cont'd)																	
400D	4/18		4/18							17	T	T						
401	4/21	1928	4/22	0520	9	52	9	52	0	3	.61	.13	2.9	4.8	42.4	.70	.64	Rain
402	4/26	0430	4/26	0910	4	40	4	40	0	4	.12	.06	2.4	2.7	45.6	.08	.18	Rain
403	4/30	1100	5/1	1538	28	38	22	46	1	4	2.74	.39	6.1	13.2	42.0	1.92	2.85	Rain, snow
404	5/7	0240	5/8	1400	35	20	15	13	3	6	.72	.17	2.9	5.2	47.3	.56	.78	Rain
404A	5/14		5/14							6	T	T						Rain
404B	5/24	2140	5/25	0230	4	50	4	50	0	10	.08	.04	3.9	6.1	45.8	.03	.06	Rain
405	5/30	1050	5/31	0430	17	40	14	40	1	5	.17	.03	4.5	6.3	51.6	.05	.02	Rain
405A	6/13	1520	6/14	0400	12	40	12	40	0	13	.05	T	3.0	3.5		T		Rain
405B	6/25		6/25							11	T	T						Rain
405C	6/26		6/26							1	T	T						Rain
405D	6/29		6/29							3	T	T						Rain
405E	7/3		7/3							4	T	T						Rain
405F	7/19	0700	7/19							16	T	T						Rain
405G	8/4	0030	8/4	0430	4	0	4	0	0	16	.03	.02				.00		Rain
405H	8/11		8/11							7	T	T						Rain
405I	8/31		8/31							20	T	T				T		Rain
405J	9/24		9/24							24	T	T					.04	Rain
Total											19.94					16.12	23.18	

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1955-56

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start		Storm stop		Storm duration		Actual raining time		Breaks in storm	Days since last rain	Storm total	Max. Hrly rain rate	Wind speed		Avg. storm temp.	Range in precipitation		Character of precipitation
	Date	Time	Date	Time	Hr.	Min.	Hr.	Min.					Storm avg.	Max. hourly	°F.	1500 ft IP-50	5200 ft IP-32	
											Inches	IPH	MPH			Inches		
			1955															
405K	10/21	1540	10/21	1640	1	0	1	0	0	27	0.01	0.01	5.2	5.2		0.01	0.04	Rain
405L	11/12		11/12							22	T							Rain
406	11/13	1150	11/14	0700	19	10	9	30	1	1	1.04	.26	3.7	7.0	41.1	.92	1.38	Rain, snow
407	11/17	0010	11/17	1040	10	30	5	40	1	3	.11	.03	3.1	3.7	41.2	.11	.10	Rain
408	11/21	0850	11/21	1651	8	1	8	1	0	4	.80	.28	3.0	6.7	45.3	.66	.69	Rain, hail
409	12/1	1146	12/2	1200	24	14	10	26	2	10	.37	.10	1.7	2.7	45.4	.50	.45	Rain
410	12/4	0040	12/4	1700	16	20	16	20	0	2	.40	.10	2.8	5.0	37.8	.46	.58	Rain, snow
410A	12/6	1000	12/6	1550	5	50	5	50	0	2	.02	.01			48.6	.00	.00	Rain
411	12/23	0010	12/23	1000	9	50	7	26	1	17	.13	.03	2.8	4.6	51.7	.16	.14	Rain
411A	12/24	2140	12/25	0300	5	20	5	20	0	1	.03	.01	3.0	3.7	46.6	.05	.02	Rain
411B	12/26	2100	12/27	0400	7	0	7	0	0	1	.09	.03	1.6	2.2	60.5	.04	.16	Rain
411C	12/31	0800	12/31	1100	3	0	3	0	0	4	T		1.2	3.3		T	.01	Rain
			1956															
411D	1/11	1515	1/11	1523	0	8	0	8	0	11	T						.00	Rain
411E	1/20	0820	1/20	1120	3	0	3	0	0	9	.01	T					.02	Rain
412	1/22	1800	1/23	0720	13	20	13	20	0	2	.10	.02	2.8	5.0	44.7	.05	.08	Rain
413	1/25	0500	1/27	1700	60	0	53	0	2	2	10.01	.68	4.2	9.2	47.7	11.01	10.60	Rain
413A	1/28	1810	1/29	1000	15	50	1	30	1	1	.02	.01	2.3	2.3		.02	.06	Rain, snow
414	1/30	1800	1/31	1030	16	30	10	40	1	1	.43	.10	5.0	8.5	39.1	.38	.55	Rain, hail, snow

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1955-56 (Cont'd)

1 Storm number	2 Storm start Date	3 Storm start Time	4 Storm stop Date	5 Storm stop Time	6 Storm duration Hr.	6 Storm duration Min.	7 Actual raining time Hr.	7 Actual raining time Min.	8 Breaks in storm	9 Days since last rain	10 Storm total	11 Max. Hrly rain rate	12 Wind speed Storm avg.	13 Wind speed Max. hourly	14 Avg. storm temp. °F.	15 Range in precipitation 1500 ft IP-50	15 Range in precipitation 5200 ft IP-32	16 Character of precipitation
											Inches	IPH	MPH			Inches		
	1956 (Cont'd)																	
415	2/16	0020	2/16	0720	7	0	7	0	0	16	.10	.05	7.3	12.6	35.4	T	.16	Rain, snow
416	2/22	1420	2/24	0715	40	55	29	10	2	6	1.42	.29	3.6	10.6	44.4	1.05	1.46	Rain, snow
416A	3/5	1640	3/6	1600	23	20	16	20	1	10	.02	T					T	Rain
417	3/31	1615	4/1	1530	23	15	5	37	2	25	.25	.12	4.4	7.8	41.1	.27	.42	Rain, snow
417A	4/2		4/2							1	T						.07	Rain
418	4/10	0400	4/13	2400	92	0	44	41	6	8	2.31	.22	3.9	5.0	40.5	2.11	3.07	Rain, snow
418A	4/17		4/18							4	T					.02	.07	Light mist
418B	4/24	0515	4/24	0520	0	5	0	5	0	6	T							Rain
419	4/26	0400	4/27	0630	26	30	16	0	2	2	1.12	.28	3.8	8.9	45.6	1.02	1.31	Rain
419A	4/30		4/30							3	T						.04	Rain
420	5/8	2017	5/10	0510	32	53	16	38	5	8	1.30	.25	4.2	9.3	46.6	1.01	1.37	Rain
420A	5/17		5/17							7	T						.02	Rain
420B	5/24		5/30				9	0	0	7	.09	.01	3.7	6.5		.05	NR	Rain and mist
420C	7/2		7/2							3	T							Rain
420D	7/25	1200	7/25							23	T					.11	.20	Rain
420E	7/26	1415	7/26							1	T							Rain
420F	8/27		8/28							32	T		3.3	3.3		.01	T	Rain
420G	9/6	0230	9/6							9	T					T		Rain
Total											20.18					20.02	23.07	

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1956-57

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
	Storm start		Storm stop		Storm duration		Actual raining time		Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed		Avg. storm temp.	Range in precipitation		
Storm number	Date	Time	Date	Time	Hr.	Min.	Hr.	Min.					Storm avg.	Max. hourly	°F.	1500 ft IF-50	5200 ft IF-32	Character of precipitation
											Inches	IPH	MPH			Inches		
	1956																	
421	10/4	0430	10/4	1450	10	20	10	20	0	28	0.27	0.05	4.1	7.4	56.7	0.41	0.15	Rain
421A	10/28	0405	10/28	1604	11	59	7	9	1	24	.06	.02	3.8	8.2	44.1	.12	.14	Rain
421B	12/4	0901	12/4							37	T							Rain
422	12/5	0916	12/6	1220	27	4	19	37	2	1	1.05	.18	2.8	4.6	46.0	1.14	.84	Rain
	1957																	
423	1/4	1035	1/5	1030	23	55	23	55	0	29	1.30	.25	3.2	7.0	45.8	1.16	1.65	Rain, snow
424	1/7	0910	1/8	0150	16	40	16	40	0	2	.40	.09	2.3	4.4	44.9	.44	.72	Rain
425	1/9	2040	1/10	1040	14	0	11	5	1	1	.90	.35	3.1	5.9	45.6	.90	1.70	Rain
426	1/12	0840	1/13	0630	21	50	21	50	0	2	3.70	.56	5.3	10.6	51.2	3.27	4.52	Rain
427	1/20	1120	1/21	0240	15	20	9	0	1	7	.37	.10	2.9	3.5	37.5	.40	.43	Rain, snow
428	1/23	1140	1/29	2010	152	30	77	59	9	2	2.19	.17	2.5	5.9	36.2	1.93	3.33	Rain, snow
428A	2/7	1625	2/11		103	35				9	.03	.01	2.9	5.4		.03	.21	Rain
428B	2/16		2/20							5	.01		2.5	2.9		.02	.02	Rain
429	2/22	2330	2/23	1635	17	5	11	55	2	2	1.78	.36	6.0	11.1	49.6	1.36	2.23	Rain
430	2/28	1000	3/2	0300	41	0	19	0	2	5	1.08	.39	5.2	8.7	46.8	1.09	1.11	Rain
431	3/9	0725	3/10	0300	19	35	19	35	0	7	.90	.34	4.1	7.0	41.7	.52	.53	Rain, hail IF-50
431A	3/12	0506	3/12							2	T							Rain

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1956-57 (Cont'd)

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start: Date	Storm start: Time	Storm stop: Date	Storm stop: Time	Storm duration: Hr.	Storm duration: Min.	Actual raining time: Hr.	Actual raining time: Min.	Breaks in storm	Days since last rain	Storm total	Max. hrly. rain rate	Wind speed: Storm avg.	Wind speed: Max. hourly	Avg. Storm temp. °F.	Range in precipitation: 1500 ft: IF-50	Range in precipitation: 5200 ft: IF-32	Character of precipitation
											Inches	IPH	MPH			Inches		
	1957 (Cont'd)																	
432	3/16	0250	3/17	0030	21	40	14	10	2	4	.64	.27	4.1	8.9	40.2	.57	.74	Rain, hail at TB
432A	3/19	0900	3/19	1100	2	0	2	0	0	2	.01							Rain
432B	3/21		3/21							2	T							Rain
433	4/17	1340	4/18	1900	29	20	16	0	2	27	.90	.23	3.4	5.7	47.2	.70	.97	Rain
434	4/19	2400	4/21	1740	41	40	20	55	3	1	.99	.25	3.0	6.5	40.1	1.08	1.06	Rain, snow
434A	4/22	2400	4/23	0140	1	40	1	40	0	1	.01	.01	2.6	2.9		T	.12	Rain
434B	5/7	0800	5/7	1100	3	0	3	0	0	14	.03	.02		4.4		.00	T	Rain
435	5/10	1500	5/11	2400	33	0	17	24	3	3	1.13	.28	3.1	5.2	45.7	.68	1.15	Rain
435A	5/14	1520	5/14	1730	2	10	2	10	0	3	.04	.04	2.5	2.5	47.8	.04	.13	Rain
436	5/18	1840	5/19	0510	10	30	10	30	0	4	1.46	.29	4.9	7.0	52.8	1.55	1.36	Rain
437	5/20	1410	5/21	0110	11	0	7	50	1	1	.13	.03		2.4	47.8	.11	.20	Rain
437A	5/22		5/22							1	T	T						Rain
437B	5/23	0826	5/23	1100	2	34	2	34		1	.03	.02			47.7	T	.13	Rain
437C	5/24		5/24							1	T							Rain
437D	6/8	0700	6/8							15	T		2.4	3.7		.42	.43	Rain
438	6/9	1540	6/10	2250	31	10	18	40	2	1	.38	.06	2.7	5.4	53.2			Rain
438A	7/2	0330	7/2	0750	4	20	1	12	1	22	.02	.01	3.6	8.5	69.8			Rain
Total											19.81					17.94	23.87	

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1957-58

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start: Date	Storm start: Time	Storm stop: Date	Storm stop: Time	Storm duration: Hr.	Storm duration: Min.	Actual raining time: Hr.	Actual raining time: Min.	Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed: Storm avg.	Wind speed: Max. hourly	Avg. storm temp. °F.	Range in precipitation: 1500 ft IF-50	Range in precipitation: 5200 ft IF-32	Character of precipitation
											Inches	IPH	MPH			Inches		
	1957																	
439	10/11	0150	10/11	1810	16	20	14	17	1	101	1.58	0.38	3.4	6.5	50.7	1.81	1.86	Rain
440	10/13	0829	10/14	0500	20	31	20	31	0	2	.71	.21	2.7	3.6	51.7	.57	.83	Rain
441	10/19	2300	10/21	1320	38	20	16	30	4	5	1.08	.82	3.4	8.6	47.4	.81	.69	Rain, snow
442	10/26	0735	10/26	1040	3	5	3	5	0	5	.10	.07	6.2	7.2	60.3	.05	.15	Rain
442A	10/28	0620	10/28	0620						2	T							Rain
443	10/29	1915	10/31	1440	43	25	15	36	3	1	.59	.28	6.2	7.2	55.8	.60	.67	Rain
444	11/2	0739	11/5	1430	78	51	40	41	4	2	1.63	.36	3.5	8.9	43.7	1.18	2.41	Rain, hail
444A	11/16	1415	11/16	1700	2	45	2	45	0	11	.02	.01	2.4	3.3	47.5	.09	.04	Rain
445	12/4	1908	12/5	1700	21	52	18	57	1	18	1.98	.61	4.1	12.1	42.8	1.76	2.62	Rain
446	12/15	0339	12/17	0310	47	31	39	25	1	10	6.60	.63	5.9	13.3	52.1	5.75	10.00	Rain
	1958																	
446A	1/10	0542	1/10	0720	1	38	1	38	0	24	.04	.03			45.2	T	.03	Rain
447	1/24	1600	1/26	2230	54	30	34	30	5	14	3.77	.36	3.5	11.8	48.9	4.17	4.32	Rain
447A	1/30	0630	1/30	0640	0	10	0	10	0	4	.01	.01				T	.02	Rain
448	2/2	1500	2/5	0240	59	40	57	40	1	3	6.05	.38	4.3	11.5	47.3	6.14	9.34	Rain, sleet
448A	2/8	1340	2/8	1700	3	20	3	20	0	3	.02	.01	4.3	7.2	52.8	.03	.03	Rain
448B	2/12	1330	2/12	2400	10	30	5	0	1	4	.04	.01	3.2	3.7	50.2	T	.03	Rain
449	2/18	2130	2/19	1320	15	50	15	50	0	6	2.21	.41	5.5	9.6	47.0	1.87	2.59	Rain
450	2/25	0120	2/25	1530	14	10	9	2	2	6	1.50	.38	5.5	11.9	49.2	1.34	1.46	Rain
451	2/28	1630	3/1	0740	15	10	3	40	1	3	.38	.18	5.5	9.6	38.9	.64	.51	Rain
452	3/6	0445	3/7	0510	24	25	18	13	2	5	1.42	.24	2.4	7.7	34.7	1.26	1.96	Rain, snow

SAN DIMAS EXPERIMENTAL FOREST

Storm Data
Tanbark Flat Field Headquarters
Hydrologic Year 1957-58 (Cont'd)

1	2	3	4	5	6		7		8	9	10	11	12	13	14	15		16
Storm number	Storm start Date	Storm start Time	Storm stop Date	Storm stop Time	Storm duration Hr.	Storm duration Min.	Actual raining time Hr.	Actual raining time Min.	Breaks in storm	Days since last rain	Storm total	Max. hrly rain rate	Wind speed Storm avg.	Wind speed Max. hourly	Avg. storm temp. °F.	Range in precipitation 1500 ft IF-50	Range in precipitation 5200 ft IF-32	Character of precipitation
											Inches	IPH	MPH			Inches		
	1958 (Cont'd)																	
453	3/10	2045	3/14	0300	78	15	26	45	4	3	.97	.24	3.1	8.0	39.2	.70	1.07	Rain, snow, sleet
454	3/15	0800	3/17	0900	49	0	31	10	2	1	3.16	.41	3.6	8.9	47.4	3.04	3.81	Rain
455	3/20	1350	3/21	0300	13	10	13	10	0	3	.81	.16	3.1	6.2	45.9	.72	.89	Rain
456	3/21	2220	3/22	0400	5	40	5	40	0	1	.90	.34	3.7	5.4	45.2	1.07	1.13	Rain
457	3/27	0745	3/27	1910	11	25	7	3	1	5	1.08	.34	4.7	6.7	41.5	1/ 1.01	1.23	Rain, trace of hail
457A	3/30	1430	3/30	2230	8	0	8	0	0	3	.05	.03	2.9	3.8	48.2	.08	.08	Rain
458	3/31	1125	4/2	0200	38	35	30	55	1	1	4.51	.58	4.6	18.0	43.4	3.79	4.92	Rain
459	4/2	1220	4/4	0350	39	30	24	10	3	0	3.67	.66	5.7	21.6	43.3	2.20	3.23	Rain
460	4/6	0852	4/7	1300	28	8	21	38	1	2	2.27	.34	3.5	8.7	37.5	2.52	2.57	Rain, snow
460A	4/30		5/2						2	23	T						.01	Heavy fog, rain
460B	5/8		5/8						0	6	T					T		Rain
461	5/11	0646	5/12	0100	18	14	11	4	1	3	.12	.06	3.6	5.5	49.7	.05	.14	Rain
461A	6/16	0750	6/16	0900	1	10	1	10	0	35	.02	.02			68.7	T)		Rain
461B	8/13	0320	8/13	0350	0	30	0	30	0	58	.02	.02	4.1	5.4	68.0	)		Rain
462	8/15	0830	8/15	1505	6	35	6	35	0	2	.49	.35	3.8	6.3	74.2	.52)	.71	Rain
463	9/23	0300	9/23	2300	20	0	15	0	1	39	.28	.14	3.0	4.2	54.5	.24	.61	Rain
Total											48.08					44.01	59.96	

1/ .06 rain on 3/23

California's Timber Industries

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some facts and figures

by Harold L. Baker

MISCELLANEOUS PAPER No. 38
SEPTEMBER 1959

PACIFIC SOUTHWEST
FOREST AND RANGE
EXPERIMENT STATION

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ACKNOWLEDGMENTS

Dean Henry J. Vaux, of the School of Forestry at the University of California, participated in the writing of the first draft of this report, and Richard H. May of the Station staff, helped in collection and tabulation of the basic statistics and reviewed the manuscript in detail. Their assistance is gratefully acknowledged.

Most of the data presented are from published and unpublished Forest Service sources.

CALIFORNIA'S TIMBER INDUSTRIES--
SOME FACTS AND FIGURES

By
Harold L. Baker[1]

Miscellaneous Paper 38
September 1959

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE
EXPERIMENT STATION

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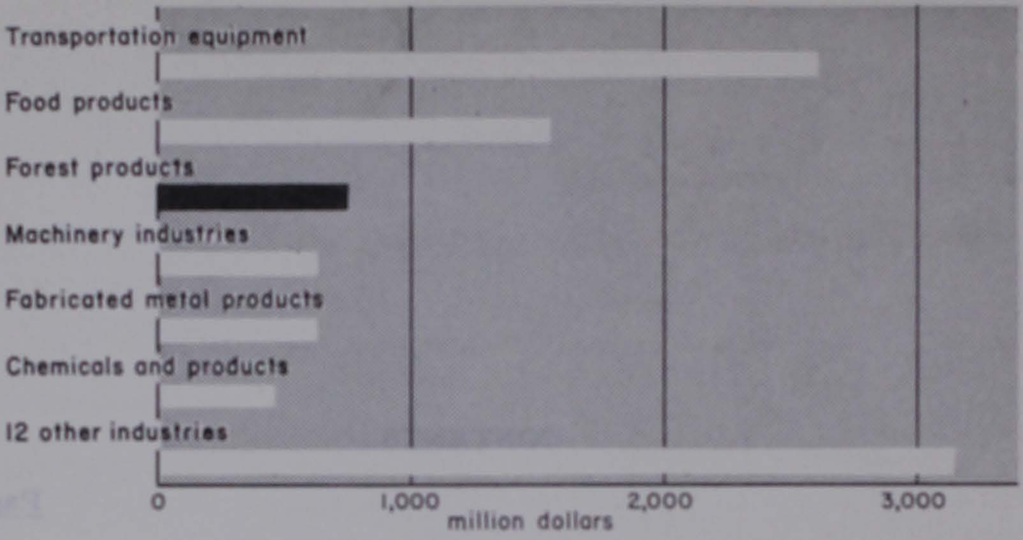


Source: Economic Survey Series No. 6a, 1957-1958. California Chamber of Commerce

Figure 1 - Value added by manufacturers for principal industries in California, 1955.

Table 1. --Annual payrolls, employment, and average annual earnings per employee, by major industry group, California, 1955

Major industry group	Annual payrolls	Number of employees	Annual earnings per employee
	Million dollars	Thousands	Dollars
Transportation equipment	1,517	288.6	5,256
Food products	624	149.9	4,163
Forest products			
Lumber & wood products	303	58.9	5,144
Paper & allied products	103	21.8	4,725
Furniture & fixtures	128	25.5	5,020
Total	534	106.2	5,028
Machinery industries	415	74.4	5,578
Fabricated metal prod.	375	75.8	4,947
12 other industries	2,031	434.4	4,675
All industries	5,496	1,129.3	4,867

U. S. Census--Census of Manufactures

CALIFORNIA'S TIMBER INDUSTRIES--
SOME FACTS AND FIGURES

By Harold L. Baker

Forest industries were among the earliest manufacturing enterprises established in California. The first steam-powered sawmill was established at Bodega in 1843, and it was in the tail race of Sutter's sawmill at Coloma that John Marshall made his historic gold strike in 1848. The Gold Rush created an immediate demand for lumber, and many new mills sprang up during the next few years, not only in the mining areas but also near San Francisco and Humboldt Bays. By 1855 about 80 sawmills were operating in the State, one-third of them steam-powered and the remainder water-powered.

For the past decade California has been the second largest producer of lumber in the Nation. Only Oregon produces more. In 1956 about 16 percent of the Nation's lumber production and substantial quantities of other timber products, were produced in California.

This production accounts for many millions of dollars worth of commodities each year. In 1955, value added by manufacture in these industries (lumber, paper, furniture, and allied products) totaled 879 million dollars (fig. 1). Industries wholly or partially dependent on the timber resource accounted for 9 percent of the total value added by manufacture in the State. Forest industries ranked third, behind transportation equipment and food products.

Forest products also account for a sizable share of the State's jobs. In 1955, manufacturing facilities for converting wood to finished products furnished employment for 10 percent of all workers engaged in manufacturing in California and accounted for about 10 percent of the annual payrolls of manufacturers. Forest industries provide 106,000 jobs and furnish the major means of livelihood for close to 400,000 persons. Even though employment in forest industries is often seasonal, particularly in logging operations, average annual earnings compare favorably with incomes in other manufacturing industries in California. In 1955, the average annual income of employees in the lumber and wood products industries was $5,144.

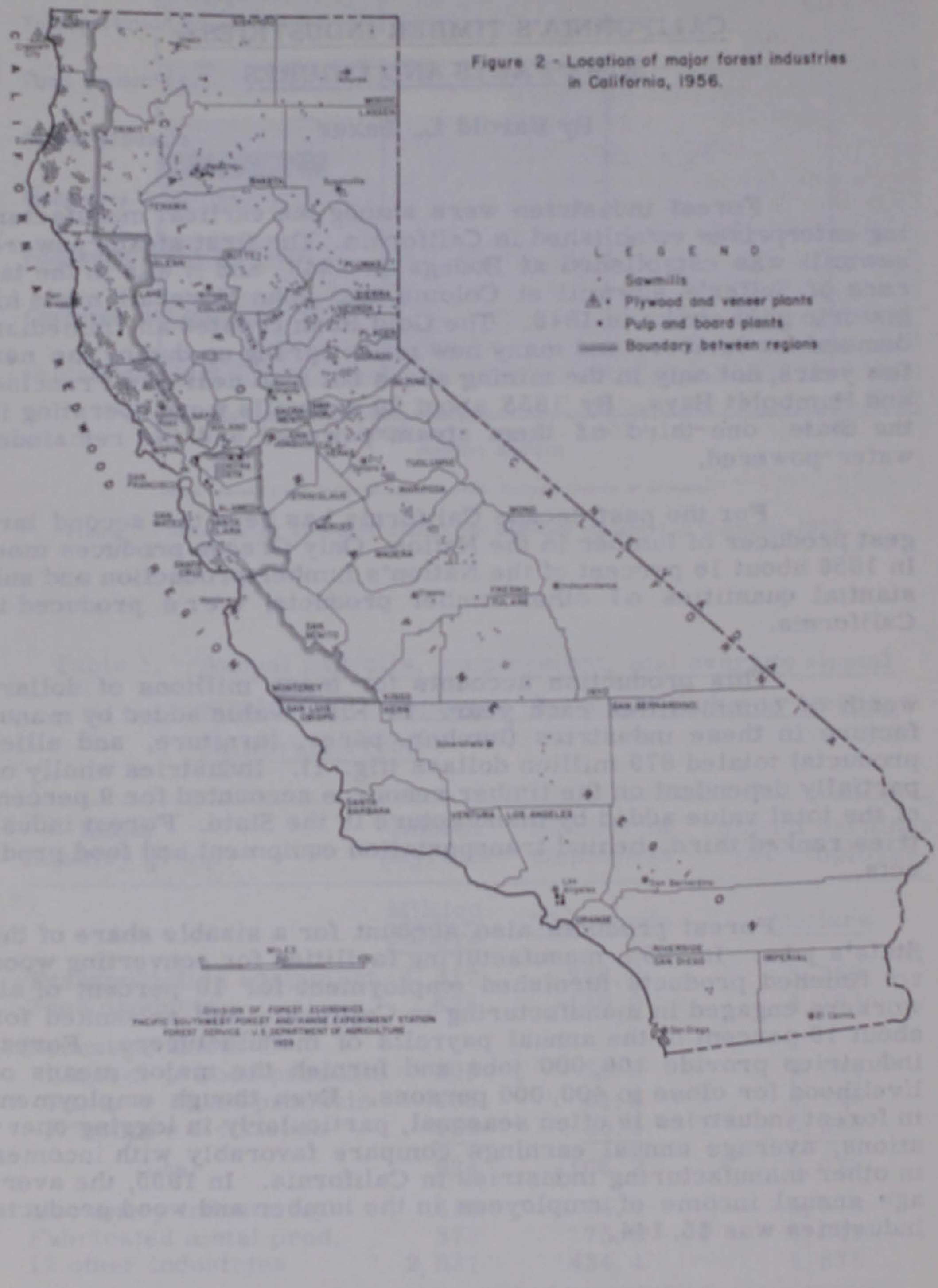


Figure 2 - Location of major forest industries in California, 1956.

L E G E N D
Sawmills
Plywood and veneer plants
Pulp and board plants
Boundary between regions
PACIFIC OCEAN
MILES
DIVISION OF FOREST ECONOMICS
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE - U.S. DEPARTMENT OF AGRICULTURE
SAN BERNARDINO
LOS ANGELES
SAN DIEGO
IMPERIAL
RIVERSIDE
ORANGE
VENTURA
SANTA BARBARA
SAN LUIS OBISPO
KERN
MONTEREY
FRESNO
TULARE
INYO
MONO
MADERA
MERCED
SAN BENITO
TUOLUMNE
MARIPOSA
STANISLAUS
ALAMEDA
SANTA CLARA
SAN MATEO
SANTA CRUZ
SAN FRANCISCO
ALPINE
SIERRA
PLUMAS
BUTTE
TEHAMA
SHASTA
TRINITY
MODOC
LASSEN
GLENN
LAKE
Los Angeles
San Bernardino
San Diego
El Centro
Bakersfield

At the end of their first century of growth, the forest industries had developed two principal elements: the lumber industry, with its pine, redwood, and Douglas-fir segments, and the plywood industry. Each of these has its characteristic products, location, organization, and economic problems. Taken together, these two major industries accounted for about 95 percent of the volume of forest products manufactured in 1956.

Supplementing these two are several smaller forest industries. They include the manufacture of pulp, poles and piling, mine timbers, fence posts, shingles and shakes, hewn crossties, tan bark, fuelwood, container veneer, charcoal, and a variety of split products. Though small, many of these industries are especially important because of the species or size of raw material they use, or because of their potentiality for expansion.

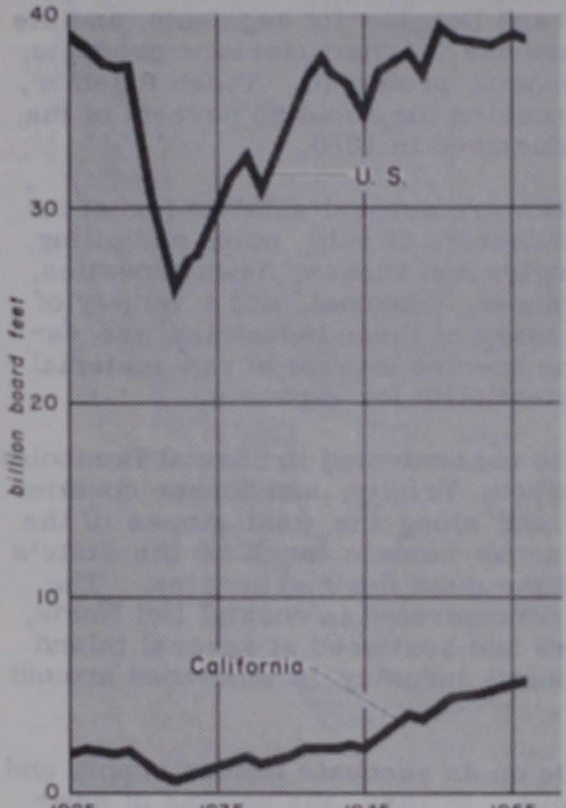
The lumber industry is concentrated in coastal Humboldt and Mendocino counties, in Siskiyou, Trinity, and Shasta counties of northern interior California, and along the west slopes of the Sierra Nevada (fig. 2). These areas contain much of the State's remaining old-growth timber of the most desired species. The plywood and veneer industry is concentrated in coastal Del Norte, Humboldt and Mendocino counties and scattered at several inland locations. The pulp and fiberboard industry is scattered around the State.

Industries' dependence on an adequate timber supply and changes in that supply is obvious. In 1953, the volume of sawtimber in California was estimated at 360 billion board feet (International 1/4-inch log scale). This material is located on 17 million acres of commercial forest land distributed throughout the State.

The future of the State timber supply will be affected by the factors of cut and growth. Average annual net total growth, based on the decade preceding 1953, was 2.9 billion board feet per year. The annual cut in 1952 was 5.7 billion board feet, largely from old growth, giving a balance of cutover growth of 2.8 billion board feet. However, the annual cut fluctuates. In 1956, 7.0 billion board feet of timber was harvested. Cut has declined since then. Growth also is changing; probably it is increasing as more of the old-growth timber is removed.

Forest land ownership also has a bearing on supply. More than one-half of the commercial forest land is in public ownership. The timber industries own only about one-fifth of the forest area, and the remainder is in farm and other private holdings.

THE LUMBER INDUSTRY



Source: The Demand and Price Situation for Forest Products

Figure 3 - Lumber production in California and the United States, 1925-1956

Lumbering is by all odds the most important of the forest industries. From the start, it expanded production moderately but steadily until the early 1940's, save for the marked fluctuations in output between the two World Wars (fig. 3). By the early 1940's production averaged about 2-1/3 billion board feet per year. Upwards of 85 billion board feet of lumber had been manufactured in the State over the hundred years ending in 1945.

Then came a dramatic change in the trend. Beginning in 1946 the output of lumber increased more rapidly than it ever had before, almost doubling in 5 years. Between 1946 and 1956 almost 50 billion board feet of lumber was produced--about three-fifths as much output as in the entire preceding century. By 1956 lumber production in California reached 5.9 billion board feet, and California had risen to a position of importance in the Nation's lumber economy.

Besides supplying a large part of the Nation's lumber, the California industry is a key producer of certain species. Redwood, sugar pine, and in some respects ponderosa pine--for a long time staples of the California lumberman--are specialty type woods. For this reason the State's lumber industry has been an important supplier of these woods in national markets. Even in the years between the two World Wars, about a third of all California lumber production was marketed outside the State, principally in the Middle West.

In 1956, 54 percent of the shipments from mills reporting to the California Redwood Association were to destinations outside the State. These mills produced 60 percent of the redwood lumber output.

Reports by California members of the Western Pine Association in 1956 showed a little over 50 percent of their shipments were to external markets. These member mills accounted for about 75 percent of the pine output of the Pine Region in 1956.

Because the Association mills tend to have widely developed marketing organizations, the figures shown are not fully representative of average conditions. However, they do serve to further emphasize the importance of the California lumber industry to the rest of the United States.

Differences in historical development, industry organization, markets, competition among species of timber, and distribution of species in the various parts of California's forest area have resulted in the development within the State of a lumber industry composed of three distinct segments: the pine industry, the redwood industry, and the Douglas-fir industry. These industries are closely associated with--but not identical to--the timber producing regions of the State (fig. 4), the pine industry with the Pine Region and the redwood and Douglas-fir industries with the Redwood Region. The Douglas-fir industry includes some Douglas-fir mills in Trinity and Siskiyou counties which are part of the Pine Region.

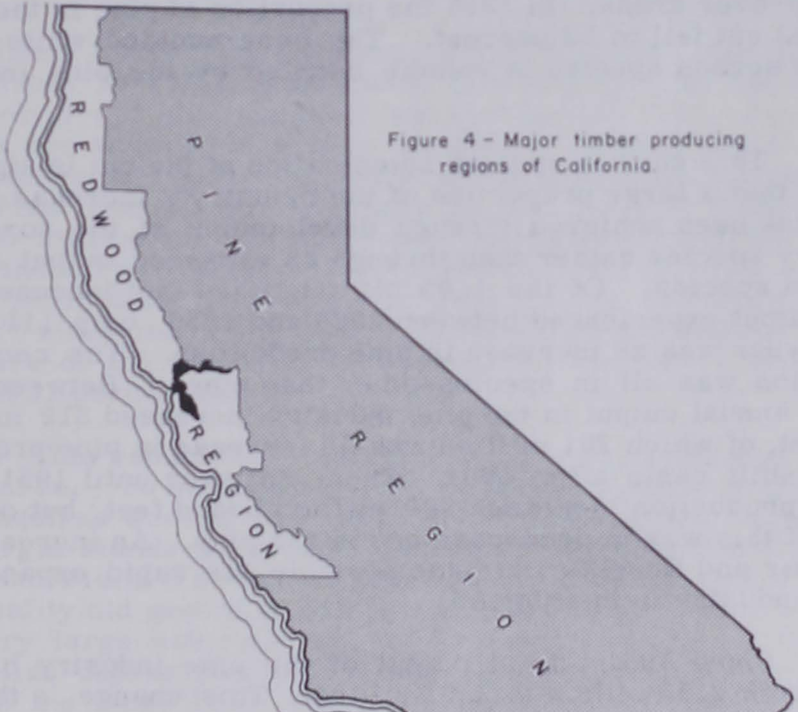


Figure 4 - Major timber producing regions of California

THE PINE INDUSTRY

The pine industry of California is the largest of the three segments of the lumber industry in the State. In 1956, it accounted for about 43 percent of total California production. About 35 percent of all U. S. ponderosa and sugar pine production originates in California, making it the largest single segment of the western pine industry.

Production was 2.5 billion board feet in 1956. This production was almost twice the 1.4 billion output in 1929. Within the past 3 decades the rate of growth in lumber production has been somewhat less for the pine industry than for the State as a whole. The rapid increase in the growth of the Douglas-fir industry during the past 15 years has obscured the increase in the pine and redwood industries.

Other important changes in the character of the pine industry have accompanied the rise in output. Before 1942 ponderosa pine and sugar pine made up more than 80 percent of all lumber cut by the pine industry. Other species, such as Douglas-fir, white fir, and incense-cedar, were cut in relatively small amounts, and large merchantable volumes of these species remained standing on logged-over areas. In 1956 the proportion of pine in the industry's total cut fell to 52 percent. The once-avoided white fir became the second species in volume handled by the pine industry (fig. 5).

This shift in species composition of the cut is significant. It means that a large proportion of the industry's increase in production has been achieved through development of the so-called secondary species rather than through an expanded output of the preferred species. Of the 1.05 billion board feet increase in annual output experienced between 1929 and 1956, only 111 million feet per year was an increase in pine production. The remaining 939 million was all in species other than pines. Between 1929 and 1941 annual output in the pine industry increased 319 million board feet, of which 291 million was an increase in pine production. The big shift came after 1941. From that year until 1951, pine industry production increased 809 million board feet, but only 1 million of this was in ponderosa and sugar pine. An increased cut of white fir and Douglas-fir made possible the rapid expansion of the pine industry in this period.

Since 1951 annual output of the pine industry has declined, from 2.59 billion to 2.51 billion. This change is the net result of a decline in ponderosa pine production, greater than the rise in the production of fir and other species.

Changes in the numbers and sizes of sawmills have also taken place (fig. 6). To produce the 1,464 million board feet annual cut in 1929 required 137 pine mills. In 1956, 340 mills cut

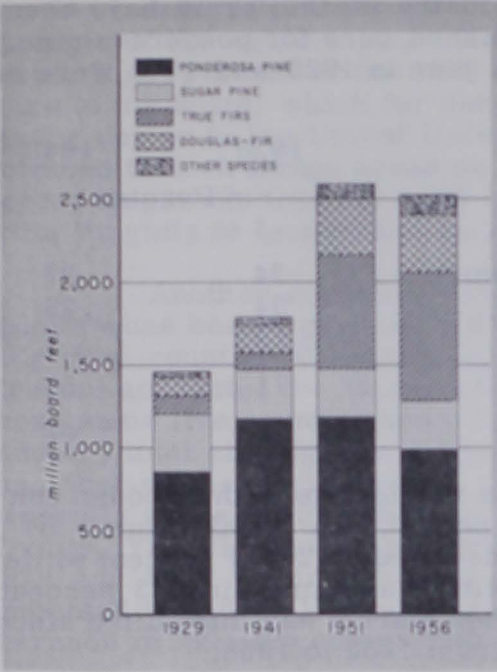


Figure 5 - California pine industry production by species in selected years

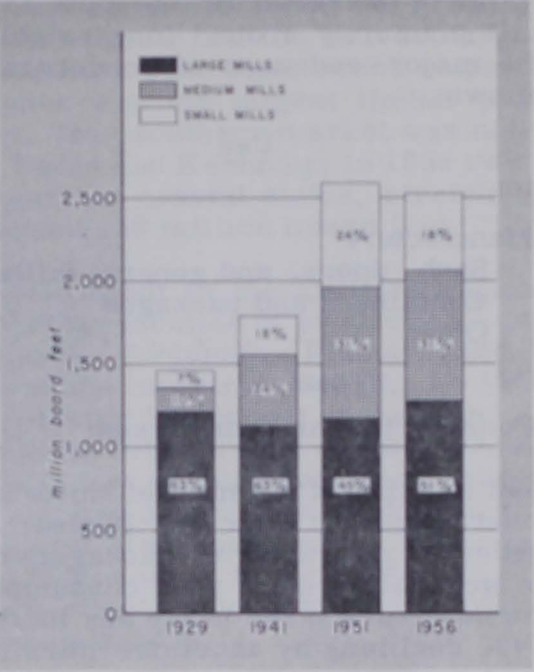


Figure 6 - California pine industry production by mill size class in selected years

2,514 million board feet. Average production per mill thus decreased from 10-2/3 million board feet per year in the earlier year to only 7-1/3 million board feet per year in 1956. Few of the new mills are as large in size as the larger pre-war mills. Moreover, some very large pre-war operations have been discontinued. An important feature of the change is that "large" mills (those cutting 25 million feet or more per year) produced 83 percent of the total industry output in 1929, 63 percent in 1941, only 45 percent in 1951, and 51 percent in 1956. Over the same period "medium" sized mills (10 to 25 million feet per year) increased their share of the cut from 10 percent in 1929, to 24 percent in 1941, and 31 percent in 1951 and 1956.

This reduction in mill size is related to a changing timber resource. To sustain a mill of 30 to 40 million feet per year output requires access to a large volume of timber. So long as heavy virgin stands were available, such volumes could be obtained from within a reasonable distance of the mill. However, as lower-quality old growth and lower-volume young stands are drawn upon, very large sawmills are hard pressed to find economical log supplies unless they own a substantial supply. Medium sized mills, on the other hand, can be supplied by a smaller timber volume. Thus the change in mill size helps bring the industry into balance with the long-term timber supply. It is not clear whether past trends in the average size of mill will continue or whether, as a result of integration, the optimum average size has already been reached.

Markets for the pine industry of California have been built primarily around long established uses for ponderosa pine. The major end-uses of ponderosa pine in 1928 and 1948 were as follows:

Use	1928	1948
	- - Percent - -	
Manufacture		
Sash, doors, and general millwork	24	27
Containers and packages	34	23
Other	13	6
Total	71	56
Construction and other uses	29	44

Most striking of the market shifts is the decline in the wooden container market. Over the 20-year period, the total volume of ponderosa pine used for packaging declined by 2-3/4 percent while the general level of pine consumption was increasing 43 percent. The downward trend in the box lumber market has intensified since 1948, declining by about one-third from 1952 to 1958.

Historically, the box market has played a vital role in the operation of the California pine industry. It provided a nearby and economical outlet for the large proportion of lower grade ponderosa pine lumber produced by the industry. But rapidly rising lumber prices and the development of competing forms of containers suitable for use in packaging California's fruit and vegetable crops have led to wholesale substitution of other types of package for the wooden box. So long as construction activity remains high and continues to absorb substantial quantities of lower grade pine boards, the full effects of the changed market picture are not likely to be felt. But a slackening of demand in the construction market could lead to a critical problem for the industry.

The geography of the pine industry's markets is also changing. Although market data are not available for all California pine mills, reports of the Western Pine Association covering most of the State's larger pine mills are indicative of trends affecting California pine producers. The proportion of reported production distributed within the State declined from 73 percent in 1946 to 47 percent in 1956. The evidence suggests that, despite the big expansion in output which took place between these two years, the absolute amount of pine industry lumber consumed in California may actually have declined. If so the withering of the box market is undoubtedly a major cause.

During the decade 1946-56, markets in the East and Midwest were expanding notably. Together, these areas took 60 percent of all shipments reported by the Western Pine Association in 1956, compared with only 38 percent in 1946. One of the reasons for these changes in market geography appears to be the growing strength of the western pine industry in competition with southern pines. Eight percent of the 1956 Western Pine Association shipments were to the South, which for decades was the largest timber producing region in the United States. This southern market was not confined to such fringe areas as Texas and Kentucky; in 1956 reported shipments into the eight southern coastal states, stretching from Virginia to Louisiana, exceeded 150 million board feet.

Another significant development in the California pine industry has been a gradual shift in the location of production. In 1929 five counties (Siskiyou, Lassen, Tuolumne, Plumas, and Fresno) accounted for 70 percent of the industry's output. By 1956 these same five counties were producing 38 percent of the pine industry total although their aggregate cut was only slightly more than that of the earlier year. The new development has moved generally to the north and west, and has centered in the Shasta-Trinity, Yuba-Plumas, and Amador-Calaveras areas. Between 1929 and 1956 the increase in production in these six counties amounted to 908 million board feet, about 85 percent of the total increase in industry output over the period.

Another indicator of this geographic diffusion is the fact that 18 out of the 30 pine-producing counties now cut 50 million board feet or more per year. In 1929 only nine counties had an industry of this magnitude. Evidently, the California pine industry has passed beyond the pioneer stage, where large untapped areas of the region await industrial development. It has entered a new period in which timber procurement problems will focus largely on accessible areas. The last decade and a half of history of the California pine region has been characterized by a major internal migration. The opportunity to continue to solve the industry's raw material problems by such migration now appears to be largely past.

THE REDWOOD INDUSTRY

The redwood industry, long synonymous with the lumber industry in the Redwood Region, was founded over a century ago. Up to 1905 it grew more rapidly than pine lumbering and was the largest forest industry in the State. But between 1905 and 1946 the scale of redwood operations was fairly stable, and the pine industry replaced the redwood in first rank. From 1946 to 1951 the redwood industry grew rapidly, and by 1956 accounted for 23 percent of the State's lumber output.

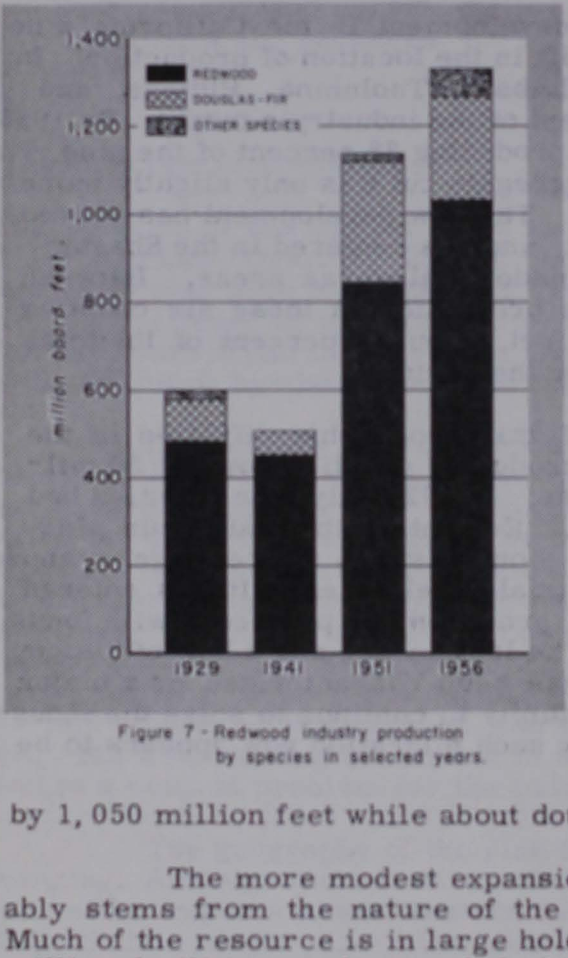


Figure 7 - Redwood industry production by species in selected years.

Lumber production by the redwood industry was 1,329 million board feet in 1956--730 million board feet greater than annual production in 1929 (fig. 7). The number of mills cutting significant amounts[2] of redwood lumber increased from 32 to 240. In the same period, the pine industry increased production by 1,050 million feet while about doubling the number of mills.

The more modest expansion in redwood lumbering probably stems from the nature of the redwood timber ownership. Much of the resource is in large holdings closely tied to established milling facilities, and a good deal of the stumpage is held as a reserve for future cutting. Not only is there less redwood timber than pine, but also the stumpage available on the open market to support expansion of redwood lumbering is much more limited than in the pine or Douglas-fir industries.

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[2] Twenty-five percent or more of annual production is redwood.

The redwood industry has responded to the recent broadening of markets by some increase in production of "white woods" (principally Douglas-fir), but a substantial proportion of the recent growth in output has been the result of a greater production of redwood. Of the 730 million board foot increase in annual output between 1929 and 1956, 548 million was redwood. Virtually all of this increased redwood production was achieved after the end of World War II.

Redwood markets emphasize those uses where durability, straightness of grain, availability in large sizes, and other distinctive properties of the timber are important. In 1948 major end uses of redwood were:

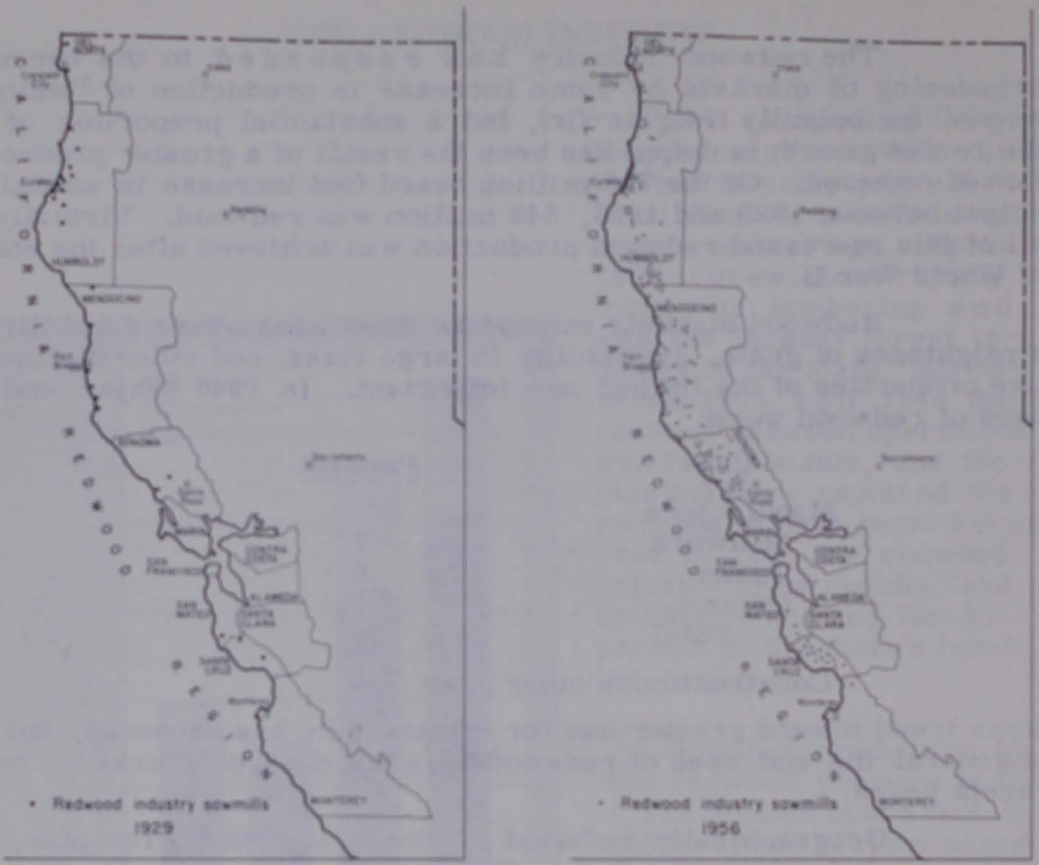
Use	Percent
Manufacture	
Millwork	7
Tanks	6
Other	7
Total	20
Construction & other uses	80

Some trend toward greater use for manufacture has shown up, but in general the end uses of redwood have not changed markedly in recent years.

Geographically redwood markets, like those for pine, have expanded outside the State. For example, in 1945 mills reporting shipments to the California Redwood Association showed 38-1/2 percent of their shipments going to destinations outside California. In 1956 interstate shipments accounted for 53 percent of the total. Redwood markets are particularly well developed in Ohio, Illinois, Texas, and adjacent states.

Unlike the pine industry, the redwood industry has not shifted its location of production a great deal. Such expansion as has taken place has been rather general over the producing region, except that newer mills have tended to be established further inland. (fig. 8). This stability reflects the narrow geographic range as well as the location and size of redwood timber, the need for large industrial plants to be located on major transportation routes, and the well stabilized pattern of control over timber supply, with only 5 owners each controlling more than 50,000 acres of timberland in 1953, and 10 more holding between 20,000 and 50,000 acres.

Nevertheless, the industry has spread out. Humboldt County, long the center of the redwood industry, usually accounted for two-thirds of all redwood lumber production before World War II. Now it accounts for less than half the total (42 percent) and adjacent Mendocino County is beginning to rival Humboldt as a supplier of redwood. Thus, in the redwood industry, too, the last decade has brought a new stage of development in which few timber areas are so remote from a sawmill as to be considered inaccessible.



HUMBOLDT
MENDOCINO
SONOMA
CONTRA COSTA
SAN FRANCISCO
ALAMEDA
SAN MATEO
SANTA CLARA
SANTA CRUZ
MONTEREY
• Redwood industry sawmills
1929
• Redwood industry sawmills
1956

Figure 8 - Despite the growth in output, the general location of redwood industry production has remained quite stable.

THE DOUGLAS-FIR INDUSTRY

The Douglas-fir industry is a newcomer to California. Before 1941 Douglas-fir normally accounted for about 10 percent of total State production. Most of this was cut in redwood and pine industry sawmills from Douglas-fir timber growing as a minor component in pine and redwood stands. Few mills made Douglas-fir the basis of their operations and few were located within the forest areas where Douglas-fir is the principal species. California Douglas-fir was "submarginal" in the face of the ample low-cost supply of this species flowing from Washington and Oregon to nationwide markets.

The lumber shortage of the war years permanently altered this situation. Beginning in 1941 Douglas-fir production rose both in actual output and in proportion of total cut. Some of this increase resulted from expansion in the established pine and redwood industries. But the really spectacular rise which began in 1946 resulted primarily from new plants designed to cut Douglas-fir, first in the Redwood Region and later in the adjacent northwestern edge of the Pine Region. By 1956, 267 sawmills were engaged primarily in the manufacture of Douglas-fir (fig. 9). Production by such mills had grown in 10 years from 130 million to 2,038 million board feet per year.

Naturally enough the Douglas-fir industry in California was closely tied geographically to the established pine and redwood industries at its inception. Transportation, equipment, and manpower were all most readily available on the margins of the Douglas-fir areas where they adjoined existing pine or redwood operations. At first much of the production of Douglas-fir was by mills set up to cut redwood and pine. As time goes on this industry seems likely to occupy a more and more independent position.

Markets for Douglas-fir lumber differ from those for pine and redwood both in respect to end-use and geography. Douglas-fir markets center on construction uses. Manufacturing and container uses are distinctly secondary outlets. Moreover, California Douglas-fir is in direct competition with the established fir producers of the Pacific Northwest. As a result, out-of-state markets are much less important than to pine and redwood producers. It is estimated, for example, that more than three-fourths of the output of the Douglas-fir industry in Humboldt County is marketed within California, where the domestic mills have important transportation advantages over their northwest competitors.

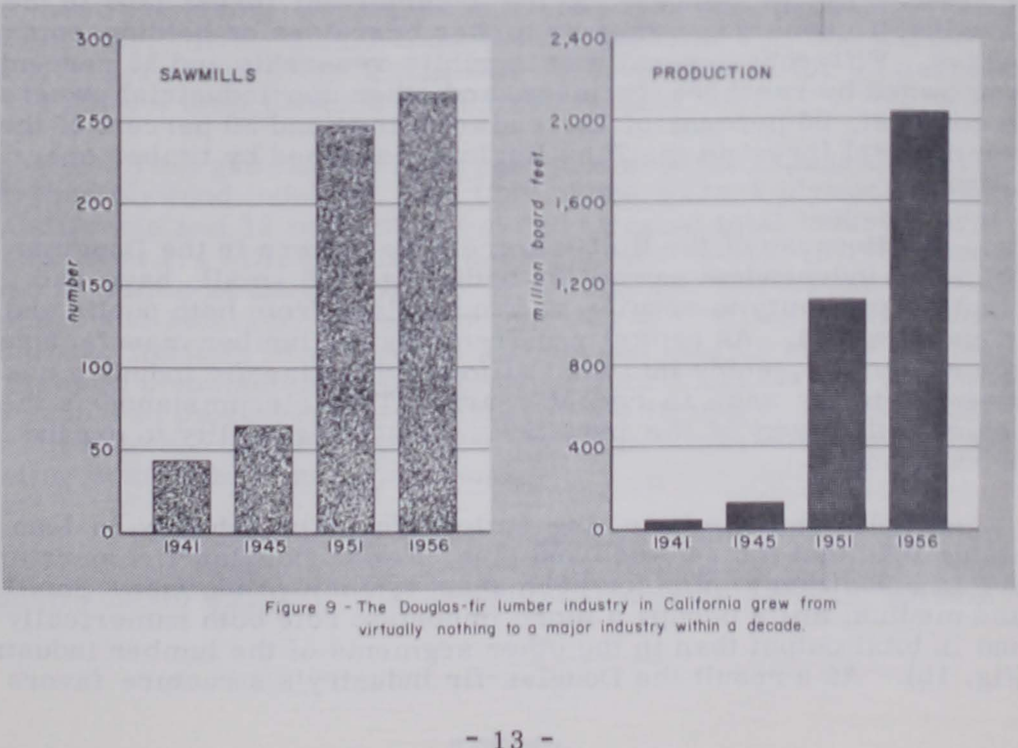


Figure 9 - The Douglas-fir lumber industry in California grew from virtually nothing to a major industry within a decade.

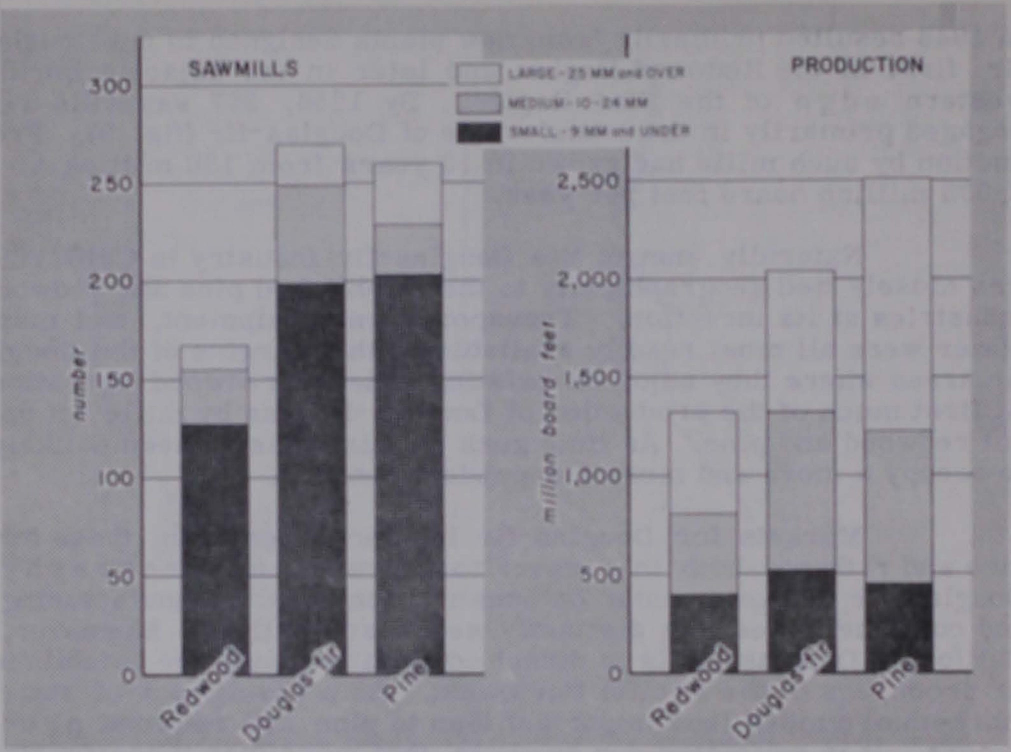


Figure 10 - Number of sawmills and lumber output in the three segments of California's lumber industry, 1956

The Douglas fir lumber industry controls relatively little of its basic timber resource through large scale ownership. In 1948 only 13 percent of the commercial forest land in the Douglas-fir zone was owned by timber operators or holding companies. Fifty-one percent was in public ownership and 36 percent was owned by ranchers, farmers, and other non-industrial owners. In contrast, 59 percent of the redwood zone and 30 percent of the commercial forest in the Pine Region was owned by timber operators.

Because of the timber ownership pattern in the Douglas-fir zone, independent sawmills, both large and small, have had ample opportunity to acquire raw materials from both public and private owners. As capital requirements for lumber manufacture are rather low, entry into the California Douglas-fir industry has been relatively easy in recent years. This circumstance is the basic explanation of the industry's surprising ability to expand production.

At the same time, the outlook for this industry is less stable than that for redwood and pine. Fewer Douglas-fir operators are in a position to plan for permanent lumber production. Small and medium mills occupy a more important role both numerically and in total output than in the other segments of the lumber industry (fig. 10). As a result the Douglas-fir industry's structure favors expansion well beyond the capacity of the resource for permanent production. Also, it provides opportunity for a sharp reduction in number of operators and volume of output if the timber supply is reduced.

The Douglas-fir lumber business is in direct competition with the softwood plywood industry both for markets and raw material. Plywood has made substantial inroads into established construction industry markets for such uses as concrete forms, roof and wall sheathing, floors and sub-flooring, and for interior applications. Furthermore, the better grades of sawmill logs are suitable for plywood manufacture, and the product value per unit of wood used is higher for plywood than it is for lumber. As a result, Douglas-fir sawmills meet stiff competition for the better grades of logs. In recent years, markets have been generally strong for all grades of Douglas-fir lumber, so the effects of such competition have been minimized. But any decline in demand for lumber would weaken the ability of Douglas-fir sawmills to compete with the plywood industry for high grade logs.

THE PLYWOOD AND VENEER INDUSTRY

Among the major producers of forest products in California, plywood is an "infant" industry. However, it is a lusty infant which has grown from 2 plants in 1946 to 21 plants in 1956, with an annual production of 725 million square feet (3/8-inch basis). In California, plywood has been manufactured from ponderosa and sugar pine since 1911. However, only three plants are now producing pine plywood. Most of the production is Douglas-fir. Even though Douglas-fir plywood was not manufactured here until after World War II, it accounted for 93 percent of the State's total plywood production in 1956.

This growth has been part of a general expansion in the softwood plywood industry. In 1946 there were 2 plywood plants in California and 33 in Washington and Oregon; total industry production was 1.4 billion square feet (3/8-inch basis). In 1956 there were 21 plants in California, 99 in the Pacific Northwest, 1 each in Idaho and Montana; industry output was 5.4 billion square feet. Continued industry-wide growth will depend largely on the success of plywood manufacturers in expanding their markets and enlarging the supply of peelable logs available to the industry. During the past decade the industry has established an impressive record in dealing with both of these problems.

Failure to solve these problems could have a greater impact on the State's timber economy than the size of the plywood industry might suggest. Its labor requirements per unit volume of logs are more than twice those needed to manufacture finished lumber. As a result, the plywood industry employs a significantly larger number of workers, per thousand feet of timber consumed, than the lumber industry.

A new development in the California industry is the construction and operation of green veneer plants. These plants peel veneer which is shipped green to other operators for drying and laying up in plywood panels. Douglas-fir is the major species used for this purpose. At the beginning of 1950, only one green veneer plant operated in California. In 1954 there were twelve. By 1956, 17 green veneer plants were operating in the State, indicating a continuing rise in this part of the industry.

THE WOOD FIBER INDUSTRY

The California wood pulp industry is currently relatively small but may have great potential for future development. In 1956 pulp manufacturers consumed 66 million board-feet of logs (gross scale)--about 1 percent of the round wood used by all forest industries. This modest activity does not indicate the relatively large recent growth of the industry because it does not show the expanded use of wood chips as a source of raw material. Before 1948 use of pulpwood was restricted to less than half a million board feet per year, used in the manufacture of roofing materials. In 1956, there were 7 fiber using plants in California--1 pulp mill, 1 hardboard plant, and 5 roofing felt plants. Also in operation were two particle-board plants.

In 1956 two other plants were constructed--a pulp mill at Red Bluff and a particle board plant at Arcata. These plants are now in operation.

Until recently the wood pulp industry by-passed California as a site for its development. Technical factors related to wood and water requirements, ready availability of raw materials, skilled labor, and market outlets in other sections of the nation all combined to concentrate the industry's growth in other areas.

Now economic conditions have become more favorable to establishment of primary pulp production within the State. The better plant sites in areas outside the State are occupied, and more sites are still needed. Moreover, a growing market for pulp products is concentrated in California.

Initially the California pulp industry relied on round wood for raw materials. Much of this was sawlog size material of too low quality for use in sawmills or of species such as white fir, whose market as lumber was narrow. Additional log supplies were obtained from thinning young stands and from material too small for utilization as lumber.

Then the industry began to utilize chipped mill residues from sawmills and plywood plants. These residues have now become a principal source of raw material supply for the pulp industry. In 1952, 33 percent of the raw material used by the pulp industry (8 million cubic feet) came from mill residues. Yet, this raw material composed only 10 percent of the coarse mill residue used in the State and but 3 percent of the coarse mill residue produced. In more recent years, the quantity of mill residues used has increased substantially. Estimate for 1956 shows that mill residues now supply about 60 percent of the raw material for wood pulp in California. Even so, real opportunities exist for expanded use of the available material by new fiber-using plants.

Besides reducing waste through use of mill residues, the pulp industry has had a favorable effect in reducing the amount of residual material left in the woods after logging. Sometimes the pulpwood market has permitted salvage of substantial volumes of material left on areas previously harvested for sawlogs. Of greater importance has been the reduction in logging residues wherever it has been possible to market pulpwood at the same time that sawlogs were being removed. Opportunities for use of logging residues have slackened somewhat because of the increased use of mill residues. Also, present pulpwood prices and transportation costs are such that the economic impact of the industry on standards of utilization in the woods has been confined to areas within a 100 to 150 mile radius of San Francisco Bay.

Several factors favor further expansion of the California pulp industry. Among these are a favorable raw material supply, proximity to an expanding market for pulp products, and the long-term rising trend in nationwide demand for pulp. But to achieve such expansion, the problem of securing the necessary quantities of process water and avoiding stream pollution will need to be solved. Recent technological advances indicate that progress is being made toward solution of this problem.

Furthermore the industry will need control of a sufficiently large supply of timber to support large-scale mill operations over a long period of time. The proportion of public ownership and the stable nature of most private timberland ownership suggests that growth of the pulp industry will require integration with already established large-scale sawmill and plywood operations or outright purchase of timberland holdings adequate to support a pulp operation.

All of these factors affecting the development of the pulp and paper resources of California are discussed in a recently completed report by the State Water Pollution Control Board. This report shows that there is opportunity for considerable expansion of the pulp and paper industry in California without creating a water pollution problem.

OTHER WOOD PRODUCTS INDUSTRIES

Several other wood products industries are established in the State (table 2). In the aggregate their production is relatively minor compared to lumber or plywood. None of them appears to have the potential for future growth that the pulpwood industry has. None of them constitutes a major industry on a Statewide basis. But each is significant either in local areas or in relation to particular forest conditions.

Poles and piling are cut from Douglas-fir and ponderosa pine, and piling from eucalyptus. The market for these products fluctuates considerable from year to year but is persistent. About 24 million board feet of timber was used for these purposes in 1956. The market helps in the management of young-growth timber because it provides an outlet for certain classes of material produced in the course of thinning operations. Only few companies purchase, process, and market poles and piling; they control little or no forest land and purchase needed timber largely from farmers and other non-industrial owners.

Cooperage and container veneers have been produced for many years. The single cooperage plant in Humboldt County, which operated largely on Douglas-fir, went out of business in 1955. Several veneer plants cut packaging material from ponderosa pine. These industries used about 4 million board-feet of logs in 1956. Much of their raw material comes from sawlogs. Another component of the industry makes considerable use of veneer bolts cut between branch whorls of second growth pine. These veneer plants are usually small and operate independently of sawmills.

A small but long-established industry manufactures shingles and sawed shakes. Redwood and sugar pine are the species of timber used, mostly redwood. About 4-1/2 million board feet of logs was used for this purpose in 1956, considerably less than the volumes used in other post-war years for which records are available. Shingle and sawed shake production is centered in Humboldt and Mendocino Counties and is typically a small scale industry. For example, in 1956 some 26 manufacturers were in business, using on the average less than 175 thousand board feet of timber per year apiece.

Table 2. --Output of timber products, California, 1956

Product	Quantity	
	MM board feet	Percent
Sawlogs for lumber	6,353.3	90.5
Veneer logs and bolts	531.7	7.6
Pulp logs and bolts	51.2	0.7
Firewood	25.4	0.4
Poles, piling, and mine timbers	24.6	0.4
Split products (except shakes)	23.8	0.3
Shingle and shake bolts and box bolts	4.5)	0.1
Charcoal wood	4.0)	
Total	7,018.5	100.0

Source: California Forest Survey Release No. 35

The redwood split products industry has a greater output than the shingle and sawed shakes industry. In it, specialists produce a variety of products: stakes, fenceposts, paling, and similar items. Operations are carried out largely by hand, and the industry provides a part-time occupation for some residents of the redwood area.

Other small forest industries include those producing mine timbers, fuelwood, charcoal, and tanbark. Total production of these industries amounts to about one-half of one percent of the timber products output in California.

OUTLOOK

California is well endowed with timber resources, compared to most other states, and the timber industries are likely to continue to form an important part of the California economy for many years to come. Lumber is by far the major timber product and undoubtedly will continue to dominate the production picture, but the production of veneer and plywood has been growing rapidly and the pulp industry is off to a good start. These recent trends toward diversification of output are likely to continue, accompanied by further integration of production processes, as the timber industries adjust to changing market and timber resource conditions in the future.

BITTERBRUSH RESEEDING...

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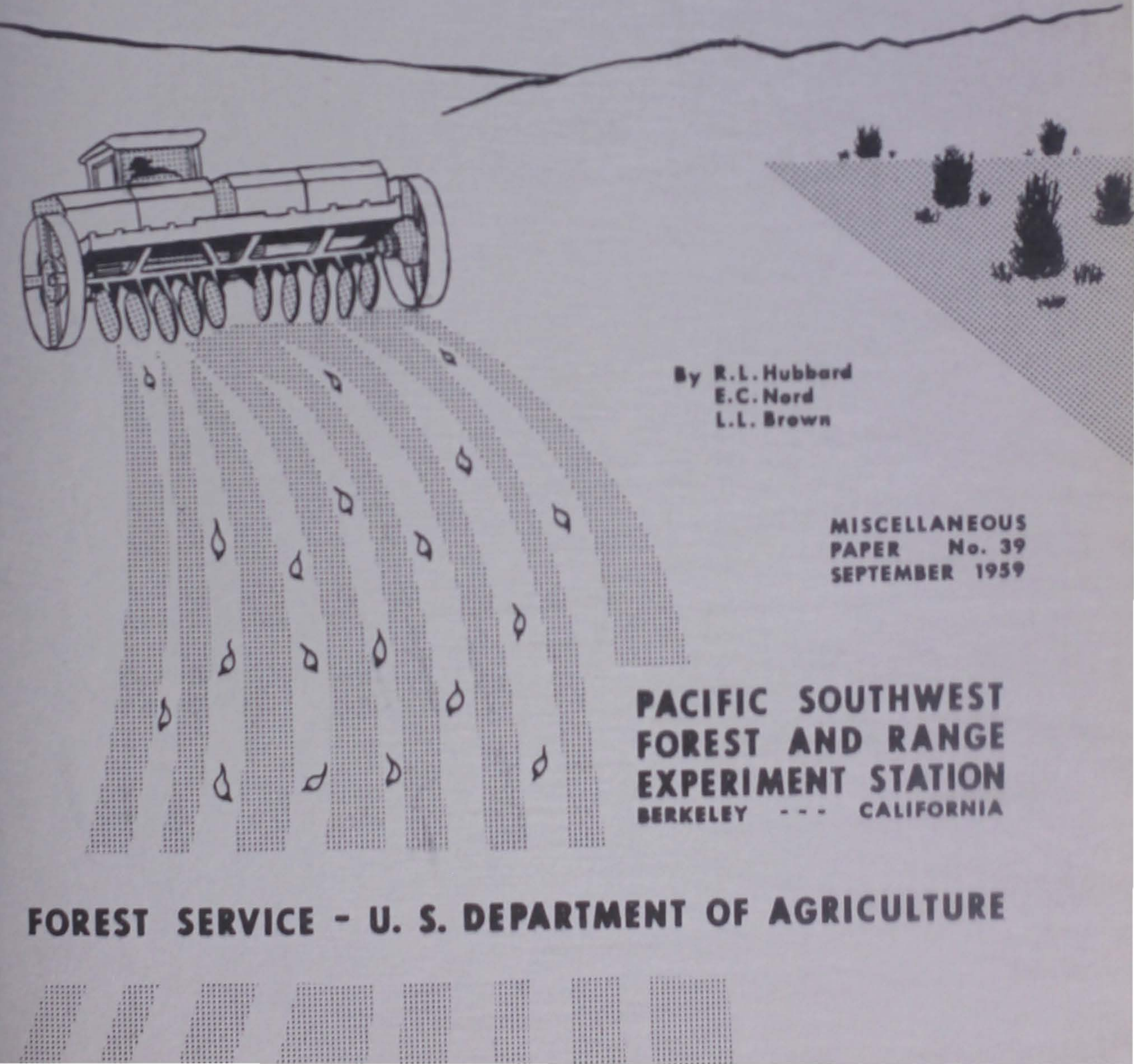
a tool for the game range manager



By R.L. Hubbard
E.C. Nord
L.L. Brown

MISCELLANEOUS
PAPER No. 39
SEPTEMBER 1959

PACIFIC SOUTHWEST
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FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

BITTERBRUSH RESEEDING - A TOOL FOR THE GAME RANGE MANAGER

By Richard L. Hubbard, Eamor C. Nord, and Lyle L. Brown
Division of Range Management Research

Miscellaneous Paper No. 39
September 1959

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION

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BITTERBRUSH RESEEDING - A TOOL FOR THE GAME RANGE MANAGER[1]

By Richard L. Hubbard, Eamor C. Nord, and Lyle L. Brown
Range Conservationists and Range Aid

Bitterbrush (Purshia tridentata) can be artifically seeded to improve critical deer ranges. This has been demonstrated on several areas in northeastern California. There is a crying need for restoration of bitterbrush ranges destroyed by fire, grazing, insects, disease, and natural succession. Some of these ranges have been important deer wintering areas. Given time, nature may restore bitterbrush on some of them--on others, perhaps not. Even where bitterbrush will come back naturally, it generally takes many decades, longer than most game managers, sportsmen, and deer are willing or able to wait. The condition of these ranges justifies the use of artificial seeding methods.

During the last few years, we've planted bitterbrush on 23 different areas varying in size from 1 to 18 acres. Some have been very successful; others have been failures. These plantings were made to test research findings and determine the practicability of range seeding.

One of the first obstacles, bitterbrush seed dormancy, was overcome by soaking the seed for 4 to 5 minutes in a 3 percent thiourea solution then drying at room temperature (Pearson, 1957; Hubbard and Pearson, 1958). In nature dormancy is broken by overwintering in the soil. The thiourea treatment makes spring planting possible.

Hubbard (1956) showed that good site preparation was another requirement of success. Site preparation reduces the number of plants competing with bitterbrush seedlings for moisture. Cheatgrass is a heavy competitor; more so than the broad-leaved, summer-annual weeds (Holmgren, 1956). Once bitterbrush seedlings are established, they persist and often achieve dominance over competing plants if protected from grazing.

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[1] Contribution from cooperative investigations between the Pacific Southwest Forest and Range Experiment Station and the California Department of Fish and Game. Work was done under Federal Aid in Wildlife Restoration Act, Pittman-Robertson Research Project W51R entitled "Game Range Restoration."

Hubbard (1956 B) reported optimum bitterbrush seedling emergence from seed planted at depths of between 1/2 and 1-1/2 inches.

Nord and Knowles (1958) facilitated seed distribution with ordinary fluted-feed drills by mixing the bitterbrush seed with loose rice hulls.

Knowing where to plant bitterbrush is as important as how to plant. According to Gardner[2] bitterbrush makes its best development on coarse textured soils that are excessively drained, rapidly permeable throughout, and have a slightly acid reaction (pH 6.0 to 7.0) to a depth of 5 feet or more. Bitterbrush generally does not grow naturally in northeastern California on soils that are saline or calcareous within 3 feet of the surface or on imperfectly or poorly drained soils.

Many of the plantings in our experience were conducted jointly by the Pacific Southwest Forest and Range Experiment Station and the California Department of Fish and Game. Although too small to provide much herbage for big game or livestock, they have demonstrated how to do the job under the usual run of field conditions.

PLANTING SITES

Some of the chosen sites were classed as good, others as intermediate, and some downright no good. All were on critical deer-winter range in need of reseeding. Also, each area could be plowed and seeded with ordinary equipment. They represented different site conditions to aid widening the applicability of research findings.

Elevation varied between 4,000 and 4,500 feet. The northernmost plantings were on the California-Oregon Interstate deer herd range in Modoc County (fig. 1). Total precipitation in this area averages about 12 inches annually with a seasonal range of 8 to 22 inches. Most of the soils are formed from basalt. The natural vegetation is predominately a sagebrush-juniper type on the edge of the pine timber belt. Fires have converted some of the areas into sagebrush-cheatgrass or other seral types. The Mears, Flukey Well, Adobe Flat, Casuse Mountain and Dead Horse sites were chosen in this general area.

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[2] Gardner, Robert A. 1956. Reconnaissance soil investigation Game-Browse restoration experimental areas and soil-bitterbrush relationships. Typed. Soil-Vegetation Survey Project, Calif. Forest and Range Expt. Sta., Berkeley, 22 pp.

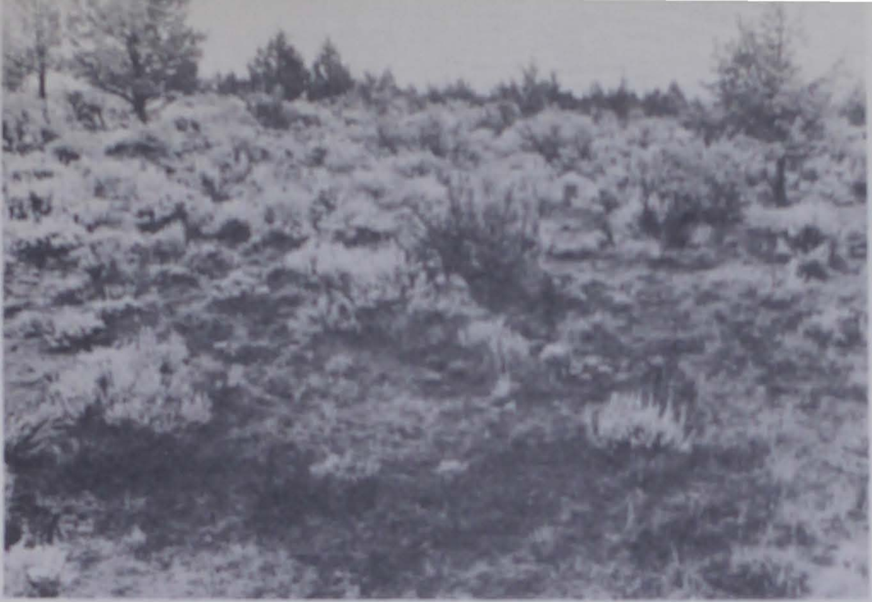

Figure 1.--Juniper, sagebrush and decadent bitterbrush must be removed from ranges to be seeded. Flukey Well-Mears sites.

Other plantings were made on the California portion of the Washoe-Lassen deer range between Hallelujah Junction and Janesville in southern Lassen County. Average annual precipitation for this area is about 10 inches with a range of 7 to 15 inches. The soils are largely derived from granite. The natural vegetation is sagebrush-bitterbrush or juniper-sagebrush with cheatgrass and a sparse stand of perennial grasses (fig. 2). Repeated burning has changed it to straight cheatgrass on some sites. Five sites, Doyle A, B, and C, Red Rock, and Hallelujah Junction, were planted in this general area.

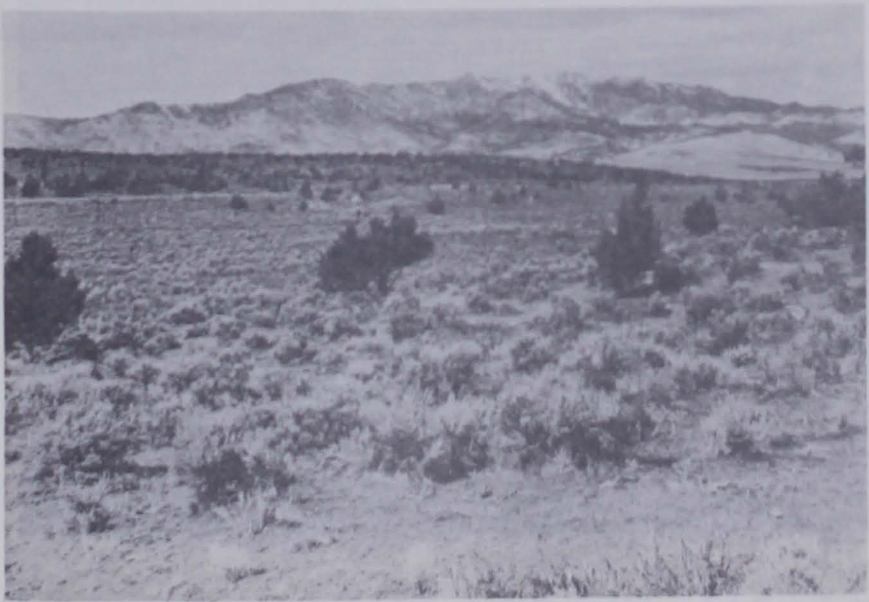

Figure 2.--General view of the vegetation type near Red Rock (Doyle), California.

Some of the sites--Mears, Flukey Well, Doyle A and B, and Dead Horse--supported natural stands of bitterbrush. These sites differed somewhat in moisture retention qualities of the top soil, and in the amount and distribution of annual precipitation. These two factors operate together either for or against planted seed during the critical germination and emergence period. Light, sandy soils dry rapidly, and consequently germination is poorer there, especially during a dry year, than on soils having good moisture retention qualities.

The soil at the Mears and Flukey Well sites belongs to the Underwood Series, a slightly gravelly loam. This series retains moisture much better than the coarser soils at Dead Horse and Doyle A and B.

Soils at the Red Rock and Hallelujah Junction areas seemed suitable for bitterbrush even though local spots had high pH at depths from 36 to 50 inches.

The Doyle C and the Casuse Mountain areas were considered marginal bitterbrush sites. The moderately well drained soils had high pH readings at 42 and 36 inch depths, respectively.

The Adobe Flat area probably never supported bitterbrush. The soil is poorly drained and it has a pH of 8.0 at depths less than 3 feet.

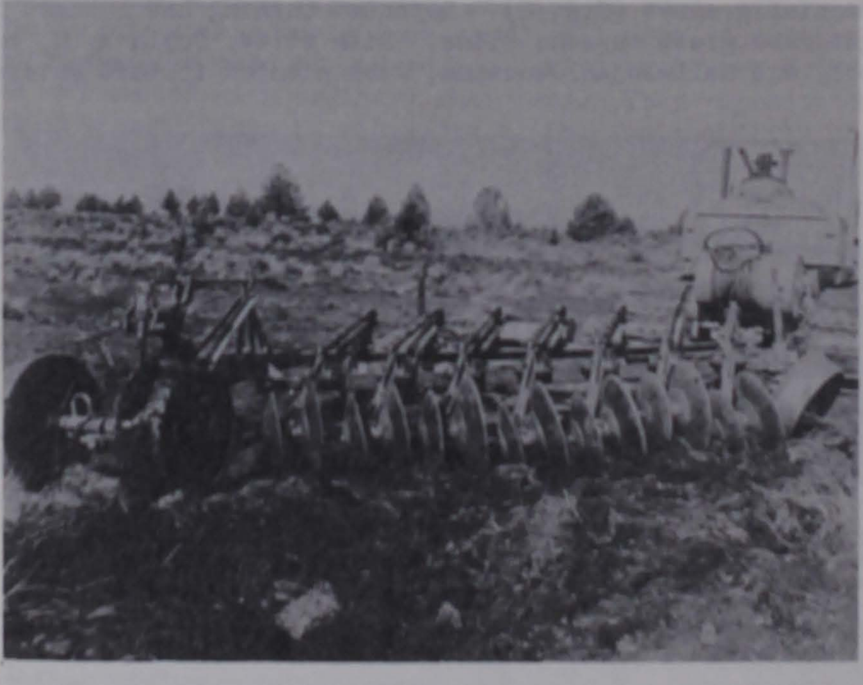

Figure 3.--The brushland plow in action on the Flukey Well 18 acre pilot planting in the spring of 1957. Before plowing, the heavy brush was removed with a brush blade mounted on this same tractor.

SITE PREPARATION AND PLANTING PROCEDURES

Plowing and drilling were done with conventional farm equipment. It was easily available and cheaper to operate than other types, but at Flukey Well in 1957 this type of equipment was not entirely satisfactory. Here we switched to heavier equipment. A D-7 tractor with brush blade removed the brush. The area was then plowed with a brushland plow and seeded with a rangeland drill (figs. 3 and 4). In 1958, conventional equipment was used to prepare the sites, but planting was done with a "baby" rangeland drill.

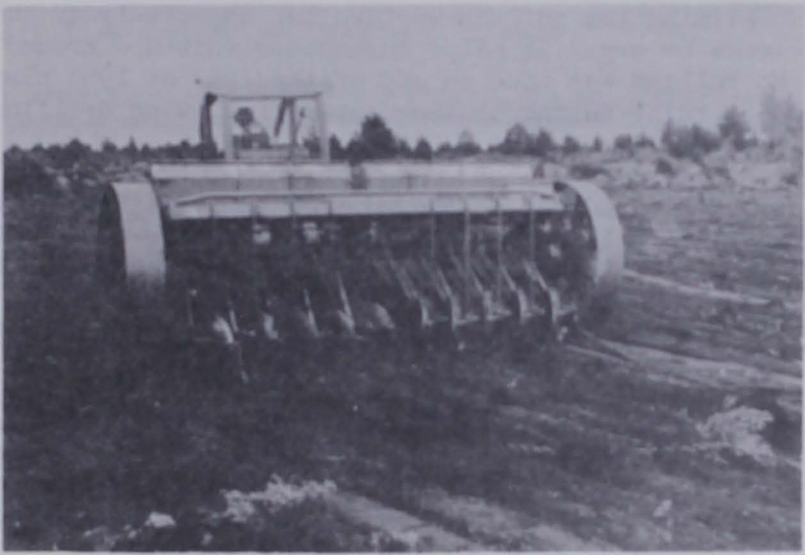

Figure 4.--The rangeland drill is ideal for planting bitterbrush seed. Mixing the seed with rice hulls gives a good seed distribution.

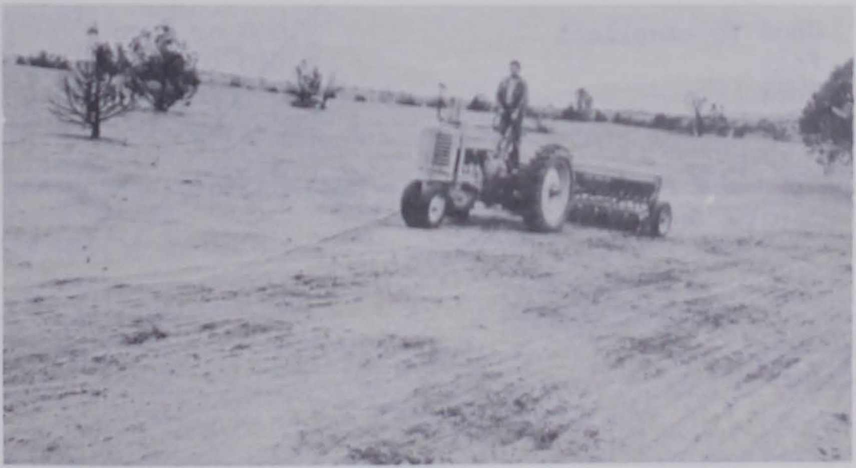

Figure 5.--Ordinary farm machinery can be used for drilling bitterbrush seed on good sites having gentle topography. Accidental wildfire removed the kind of vegetation shown in figure 2 and created a satisfactory seedbed.

Eight sites were planted in the fall; 15 in the spring. Accidental wildfire prepared the sites at Hallelujah Junction and Red Rock (fig. 5). All others were plowed. Two areas, one at Mears in 1955 and one at Flukey Well in 1957, were plowed in the spring and seeded immediately afterward. All of the 1956 and 1958 seedings were on sites plowed in the fall and allowed to settle over winter. The 1956 seedings were preceded by a light harrowing in spring to mulch the upper soil crust and knock out any germinating weed seeds. No additional spring preparation was performed on the 1958 seedings. The soil was firmed by rolling or cultipacking, or with press drill wheels. Firming the soil is worthwhile, especially if the soil is rather loose or dry. It helps to squeeze moisture around the planted seed. No rolling was done on any of the 1957 or 1958 plantings because heavy rains during or immediately following drilling firmed the soil adequately in the seed zone.

All seed used was collected from native bitterbrush stands in northeastern California. Spring plantings were with thiourea-treated seed. Untreated seed were planted in the fall. Rice hulls were mixed with bitterbrush seed in 16 to 6 proportions. Seed agitators were disengaged and drill feed regulators adjusted to sow 6 to 8 pounds of seed per acre.

Sampling for seedlings was done on 3- by 50-foot belt transects during late summer or fall after planting. Data were statistically analysed from square root transformations. Because of these transformations, the upper and lower limits of significance from the means were somewhat asymmetrical.

We classified planting success as follows:

Class:	Number of seedlings per acre
Good to excellent	3,000 or more
Fair	1,000 to 3,000
Poor	100 to 1,000
Failure	Less than 100

We consider the 2 top classes to be satisfactory stands and the other 2 to be unsatisfactory.

RESULTS AND DISCUSSION

Spring seeding on prepared seedbeds gives best results

All of the good and excellent stands and 8 out of the 11 satisfactory plantings were from spring planting on clean firm seedbeds (fig. 6). The best stands were found on soils with good moisture holding capacity. The Flukey Well and Mears areas typical of this condition also had the highest average annual precipitation. The only good planting outside the Flukey Well-Mears area was at Adobe Flat. Adobe Flat is not considered a good bitterbrush site, but the soil does retain moisture very well.

Fall seedlings produced 1,700 and 2,300 seedlings per acre, whereas comparable spring plantings produced 5,200 and 8,600 seedlings on adjoining plots.

Outstanding success came from the 1957 spring planting at Flukey Well. Stocking a year after planting was more than 12,000 seedlings per acre. The excellent stand on this area was due mainly to high site quality, good seedbed preparation before planting, and the amount and distribution of rainfall. In contrast,

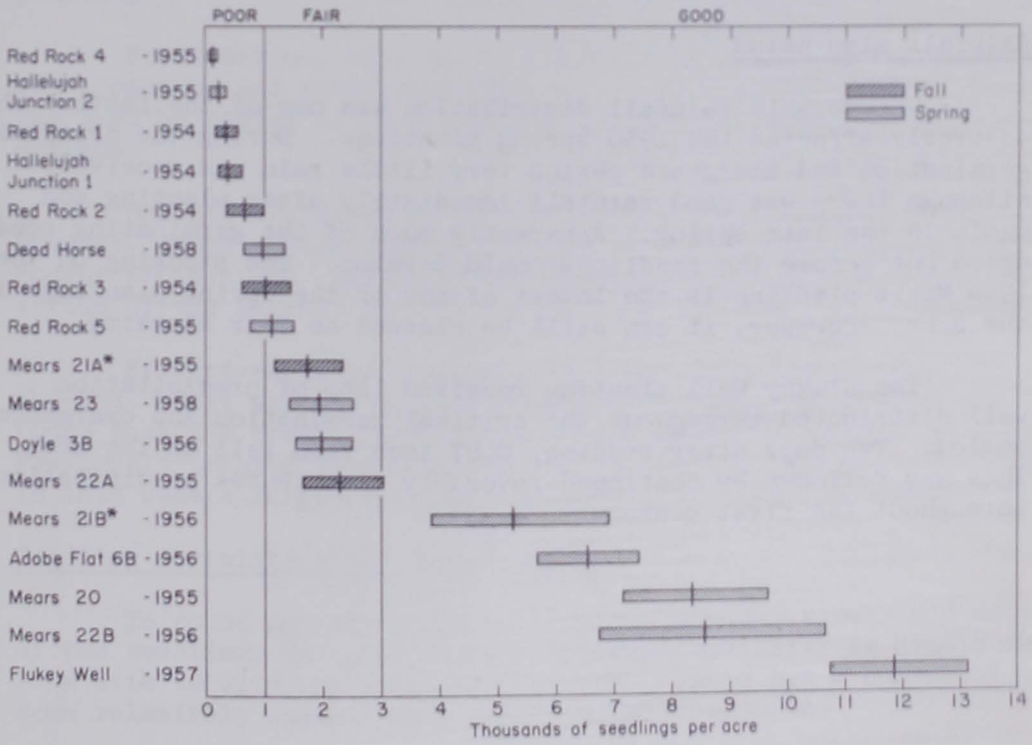

Figure 6.--Bitterbrush seedling stocking on the various drill plantings. The middle crossbar represents the mean and the 2 other crossbars are 2 standard errors above and below the mean. Stocking on the plots marked with an asterisk (*) was estimated in the second growing season. All others were estimated in the first growing season.

spring planting has not been satisfactory in Idaho. There, much better success has come from fall planting (Personal communication from Joseph V. Basile).

Not all of our spring plantings were successful, however. Four of the 6 spring of 1958 plantings failed. All four were in the Doyle and Casuse areas on soils with poor moisture holding capacity. Poor rainfall distribution, especially during the critical germination and emergence period, aggravated the situation and undoubtedly reduced the stand. Also, we found that the seed sown in 1958 did not effectively respond to the thiourea treatment as it had in other instances. Except for the 1958 failures only 2 other spring plantings failed. One was at Hallelujah Junction and the other at Red Rock--both difficult sites.

Good site preparation essential

Good site preparation cannot be over-emphasized. The seedbed must be clean and firm. All plantings that produced more than 1,500 seedlings per acre were on well prepared seedbeds. Fall-plowed areas were smoothed with a harrow and allowed to settle over winter. In spring they were harrowed lightly just before planting.

Rainfall also helps

Unfavorable rainfall distribution was one of the factors which adversely affected the 1958 spring plantings. During the critical germination and emergence period very little rain was received, although there was good rainfall immediately after planting and again in the late spring. Apparently much of the germinating seed dried out before the seedlings could develop. The stocking on the 1958 Mears planting is the lowest of any of the spring plantings in the area. However, it can still be classed as fair stocking.

The Flukey Well planting received lots of precipitation well distributed throughout the critical germination and emergence period. Two days after seeding, 0.87 inch rain fell on the area. This was followed by continued favorably distributed precipitation throughout the first season.

Insect larvae may damage or destroy seedings

Cutworms and wireworms took a toll of emerging bitterbrush seedlings on most of the plantings. On a small planting at Doyle, where we observed causes of mortality of individual seedlings, these larvae killed 98 percent of the seedlings within a few weeks after emergence (Hubbard, 1956). Enough seedlings were destroyed by cutworms on the 1955 fall planting at Doyle to turn what might have been a fairly successful planting into a failure. In the same area, the 1956 spring planting was a fair success only because we were able to go in and treat it with insecticide soon after insect damage started. Where these larvae are present in large numbers--and we don't know, as yet, how often, or where, this happens--they can totally destroy a planting.

Other conditions affecting seedling establishment

Soil crusting and cracking was evident on the 1955 fall planting at Adobe Flat. Here the seedlings failed to break through the thick crust. There was good emergence on an adjoining spring-planted plot when this soil crust was broken by harrowing before planting.

Frost action, too, may be detrimental on some soils. Cracks often open up and speed soil drying. Also frost action disturbs the seed by moving it to either a shallower or deeper depth than optimum.

Rodents are known to cut down success by removing seed. However, despite high rodent populations, we got good stands without rodent protection. Spring planting may be a partial solution by virtue of the shorter time the seed is exposed to rodent activity.

Effectiveness of the thiourea treatment should always be checked. This was not done before planting in 1958, and it was later found that the treated seed yielded only about 35 percent germination. Previously treated seed had given 90 percent or better germination. In this case a longer soaking time would have been justified.

Seedling mortality after establishment

To round out the picture, we must consider growth and mortality of the seedlings in later years. Seedling mortality is highly variable from site to site and from year to year. There are a number of causes--some relatively unimportant, others considerably so.

The major cause of seedling loss in the Flukey Well-Mears area, was frost heaving during the first winter after emergence. On the 1957 Flukey Well spring planting, mortality was about 20 percent to the end of the second growing season. On the 1956 Mears spring planting, seedling loss was about 13 percent during the first winter.

Further losses occur after the end of the second growing season. On the Mears area third season seedling mortality ranged from 10 to 23 percent. We haven't been able to single out a cause. Grazing by rabbits, deer, and in one instance by sheep has been observed. Reduction of vigor through grazing undoubtedly reduced seedling ability to compete with invading annual grasses and weeds for available moisture. A study of ungrazed bitterbrush plants (Hubbard, 1956) showed that seedlings can gain dominance over invading species if grazing is not permitted. This points up the need for control of animal numbers before attempting bitterbrush seeding.

Seeding mortality at Red Rock and Hallelujah Junction was mainly due to jackrabbits. On these areas over a 4-year period at least 80 percent of the seedlings were eaten by jackrabbits. Inside a rabbit exclosure, installed at the end of the first growing season, mortality was only about 8 percent during the same period. The amazing thing is that any seedlings at all are still living outside the exclosure.

A few years of observation are needed to determine total plant mortality between emergence and maturity. As plants get older mortality from the causes cited should decrease.

Cost of seeding

The total cost per acre on the 18-acre planting at Flukey Well was $45.62 (table 1). These are actual operating costs except an arbitrary 10 percent for miscellaneous expenses such as equipment transportation and breakdown.

More than a quarter of the total cost was for removing the brush before plowing. Light stands of brush not justifying mechanical removal can probably be burned at much lower cost.

One of the bottlenecks in reducing costs of seeding is the lack of adequate equipment hitches. Development work is underway, however, and it may not be too long before we can do the plowing, smoothing, firming, and the drilling all in one operation.

At least two other cost items, amount of seed planted and insecticide treatment, might be reduced. With perfect germination and emergence, 2 pounds of seed per acre would give satisfactory stands. Accurate forecasts of insect damage could remove the necessity for soil treatment at least in some years. Even if it is necessary to apply insecticide, application of crystalline material directly into the drill row by means of a fertilizer attachment on the drill would reduce both the amount of insecticide used and the cost of application.

Together these possibilities indicate a future bitterbrush seeding cost of $20 or less per acre.

Table 1.--Summary of costs for seeding one area of rangeland to bitterbrush

Job	Type of equipment	Cost per hour	Number of hours/acre	Cost/acre	Percent of total cost
Brush removal	D-7 Caterpillar	$10.00	1.17	$11.66	26
Plowing	D-7	10.00	.83	8.33	18
Dragging	TD-9	6.18	.50	3.09	7
Dieldrin Treatment	Ferguson wheel tractor	4.50	.44	1.99	4
Drilling	TD-9	6.18	.42	2.57	6
Seed	--	--	--	12.00	26
Dieldrin	--	--	--	1.83	4
Misc. expenses	--	--	--	4.15	9
Totals per acre	--	--	--	$45.62	100%

GENERAL RECOMMENDATIONS

The experience and research cited here do not justify a bitterbrush planting prescription for all sites and situations. They do, however, indicate the importance of several points which should be considered in any planned bitterbrush seeding program.

1. Site Selection: Pick a site which is known to have supported a good stand of bitterbrush. The soil should have high water holding capacity. Annual precipitation should average at least 12 to 14 inches.

2. Site Preparation: Do a good job of farming. Plant a clean firm seedbed.

3. Planting Time: Plant as early in the spring as possible. Spring planting minimizes seed exposure to rodents and the weather.

4. Use High Quality Processed Seed: Obtain seed locally whenever possible. Remove husks, chaffy material, and immature or empty seed. Use only the larger well-filled seed, those which sink after a few minutes soaking. Any seed that remains floating after about 3 minutes in a thiourea solution should be discarded.

5. Seed Treatment: Soak the seed for 4 to 5 minutes in a 3 percent thiourea solution and then dry. Do not wash seed after treatment. Before planting, run a germination test to make certain that the seed dormancy is broken.

6. Protection of Seeds and Young Seedlings: Use control methods wherever rodents, cutworms, wireworms, or other pests are numerous.

7. Planting Methods: Drill with a full sized or "baby" rangeland drill. To get good seed distribution, mix the seed with rice hulls in a ratio of 3 pounds of seed to 8 pounds of rice hulls. Disconnect the seed agitators in the drill seed box. A setting of 43 notches on the rangeland drill or 89 pounds barley equivalent of fluted feed drills, will seed about 6 pounds per acre. These settings should be checked by bagging the drop spouts and running the drill over a measured distance.

Planting depth should average 1 inch under favorable soil and moisture conditions--a little shallower on heavy soils, a little deeper on lighter soils.

Firm the soil after drilling with press wheels on the drill or with a roller.

8. Protection from Grazing: Livestock grazing and, so far as possible, deer browsing should be excluded from the reseeded area the first 2 years. Fencing is the only known protection against rabbits, but may or may not be justified.

SUMMARY

During the past several years, twenty-three different areas in northern California have been seeded to bitterbrush. Some of these plantings were very successful, others failed. Best results were from spring planting on bitterbrush sites receiving relatively good precipitation and having soils which retained moisture well.

Despite mortality from frost heaving, cutworms, wireworms, rabbits, and other causes, several of the plantings have good prospects of developing into well-stocked stands of thrifty bitterbrush.

The key to successful planting lies in doing a few things properly at the right time. Select a good site and farm it well. This is expensive on range lands. Costs can be reduced. How much we can afford to spend depends on how badly we need to get bitterbrush established on a particular site, and how much we are willing to pay for whatever benefits may derive. Application of the "know-how" set down here will give satisfactory results under certain conditions.

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SETTING UP A GREEN FUEL MOISTURE STUDY

PSW FOREST AND RANGE
AUG 4 1971
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By James M. Olsen

MISCELLANEOUS
PAPER No. 40
OCTOBER 1959

PACIFIC SOUTHWEST
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In November 1958 Fuel-Break[1] workers began studies of the moisture content of green chaparral fuel. Since then study plots have been established and described, and instruments obtained and installed. In March of 1959 actual data collection began. This report tells what has been done to set this project up so as to get the needed information on green fuel moisture.

Why is green fuel moisture content important? Among fuel characteristics affecting fire behavior, moisture content is probably most critical. Green fuel moisture may be a key to some possible fire resistant plants, hence its value in the Fuel-Break program. It is an element of fire danger rating, hence more precise knowledge is needed.

Green fuel moisture is affected by climatic variables, but it is not known how and to what degree. Our objective is to be able to predict moisture content at any specific time by knowing the weather history.

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[1] FUEL-BREAK--aimed at breaking up continuous brushfields for better fire control--is a joint research, pilot-plant, and administrative action program of the California State Division of Forestry, Los Angeles County Fire Department, and the U. S. Forest Service.

To meet this objective, we decided to establish permanent sample plots in several fuel types. Each plot would be equipped to measure continuously and record automatically all the weather variables that might be correlated with changes in green fuel moisture.

Since south aspects have fuel conditions that pose the toughest fire control problems, studies were started there. It was decided to sample chamise-sage and chamise-chaparral fuel types. The actual plots selected are located at the San Dimas Experimental Forest, Bell watersheds, elevation 3,100 feet.

A necessary first step was to describe the experimental areas fully.

Species composition, dead fuel content, and total fuel weights were noted - -

and litter depth was recorded.

Soils were studied and described.

Weather stations were installed for each plot.

To record wind direction and speed, anemometer, wind vane, and operations recorder were set up.

To record temperature and relative humidity, a hygrothermograph is used.

Standard 100-gram fuel sticks are attached to a recorder to keep track of the moisture content of 1/2-inch sticks.

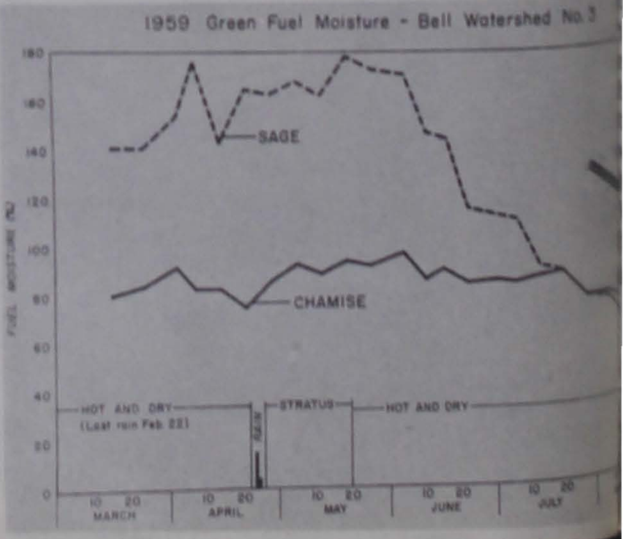
Soil moisture is measured with the nuclear probe--a new device with a radioactive element for sensing moisture.

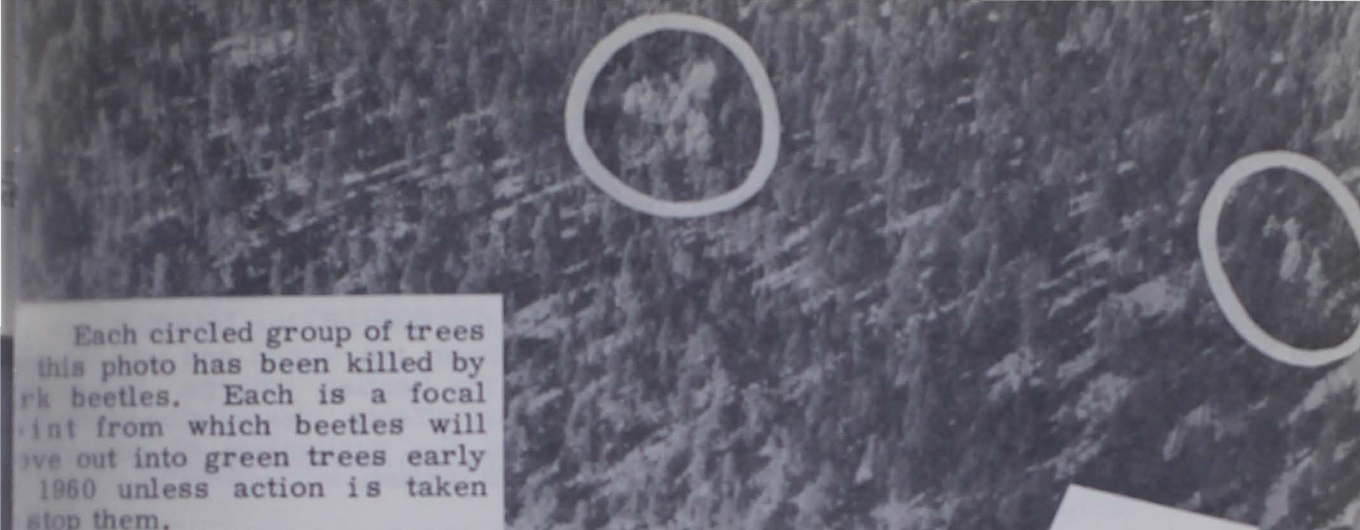
To provide a record of green fuel mo ture, foliage of chaparral is collecte flasks once a week.

The flasks are taken to the lab and water is collected by the xylene distillation process. Water content of the chaparral is computed from this information.

For the analysis of results, data fro weather recorders, soil moisture rea ings, and green fuel moisture conte determinations are tabulated and pr sented graphically. These relationshi will be further studied by use of hig speed computer. All data are punche on IBM cards for rapid analysis.

Green fuel moisture trends are entered on graphs such as the one shown to the right, which reports some preliminary results from a 1959 study. Complete results of all the fuel studies will be presented in a technical report in early 1960.





Each circled group of trees this photo has been killed by rk beetles. Each is a focal int from which beetles will ve out into green trees early 1960 unless action is taken stop them.

Photographed in Shasta unty in late October, this ene is typical of current in- ct conditions in California's ne forests--conditions which, en together, pose the great- t bark-beetle threat in more an a decade.

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BARK BEETLES THREATEN CALIFORNIA PINES

Late summer and fall surveys by tion entomologists, coupled with insect tection reports from cooperators, leave tle doubt of the prospects for increased mage. The greatest threat is to some California's finest timber: ponderosa d sugar pines in the westside mixed nifer belt. Ponderosa pine at lower evations, particularly in fringe timber, ready has been hard-hit by pine engrav- s and the western pine beetle. Sugar nes are being hard-hit by the mountain ne beetle and the same is true of cer- in lodgepole and Jeffrey pine forests in e high country, being attacked by the ountain pine beetle and the Jeffrey pine etle, respectively. One bright spot in e picture is the eastside pine zone, here many beetle-susceptible trees ve been logged in sanitation-salvage or rvest cuttings. Even these forests, wever, are not completely out of dan- r.

Compiled by
Division of Forest Insect Research

MISC. PAPER No. 41 DECEMBER 1959
PACIFIC SOUTHWEST
FOREST AND RANGE
EXPERIMENT STATION
BERKELEY — CALIFORNIA

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

Why Are Infestations Increasing?

Since the heavy spring rains of 1958, much of California has been in the grip of unusually dry and warm weather. Rainfall last winter was well below normal, and temperatures, both last fall and this, have been unseasonably warm. The effect has been double-barreled, pointing up the advance warning issued by the Station last spring. Poor conditions for timber growth have made trees less resistant to beetle attacks. And the warm weather has enabled the beetles to prosper and continue to multiply when normally they would not.

Coincidentally, natural catastrophes seem to have conspired to favor the beetles. In northeastern California, tree damage caused by lightning was unusually heavy in the summer of 1958. In the southern Sierra, snow breakage from winter storms was severe. Forest fires injured many trees. Add the slash left from some early cuttings, and the result was a plentiful supply of breeding material for bark beetles.

What Is the Outlook?

From past experience we know that bark-beetle abundance fluctuates markedly. In some years the beetles seem to be almost completely absent, and tree-killing is insignificant. In other years, like this one, the beetles gather forces and become extremely destructive. Entomologists understand some of the conditions that trigger these cycles of abundance and scarcity well enough to recognize signs of impending trouble.

SALVAGE LOGGING

This fall the supply of beetles is plentiful—probably more so than is now apparent, for while many infested trees have been detected, others have gone unseen because they were still green. Weather conditions continue to favor the beetles rather than the trees. The disastrous summer and fall fires in the pine belt this year created additional breeding material, and the high winds with some of the fall fires brought down more green trees that beetles can breed in. Most of this material will be ripe for attack next spring when the overwintering beetles emerge.

What Can Be Done?

Bark-beetle control has always been a major problem in the management of California's pine forests. Most foresters know that management must be flexible enough to cope with outbreaks like the present ones. Bark beetles now ensconced in infested trees will stay there
spring. But forest managers must pl
their beetle control strategy now if
killing of more green timber next year
to be prevented.

Salvage logging is one of the
means of disposing of infested timbe
the trees are merchantable. It is effec
however, only if the infested logs
moved from the woods and into the
before the beetles emerge. It has
beneficial effects: destruction of the
tles and the realization of cash val
from the timber.

Not all infested trees are mercha
able. And even with some that are, sa
vage logging may be impracticable,

CHEMICAL SPRAYS

impossible to accomplish in time to pr
vent the beetles from emerging. In the
circumstances other methods of destr
ing the broods must be resorted to. Fe
ing and burning, or the use of insectic
sprays are effective. The choice
method depends on the insect involved
the nature of the infestation. The Stat
can supply information on this score.

Just as important as logging or tr
ing infested trees is the disposal of tr
not yet attacked but recently injured
fire, hit by lightning, or blown down
wind. These are the trees that the bee
les will strike when they emerge ne
spring. Where these trees are conce
trated, their beetle-breeding potential
formidable. Logging such material
fore beetles can breed in it will help ke
an infestation of catastrophic proporti
from developing. The time to start act
is now.

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

PACIFIC SOUTHWEST
FOREST AND RANGE
EXPERIMENT STATION
BERKELEY - CALIFORNIA

MISCELLANEOUS PAPER
No. 42 January 1960

PSW FOREST AND RANGE
EXPERIMENT STATION
AUG 4 1971
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RANGELAND DRILL USED IN REFORESTATION IN CALIFORNIA

By
Gilbert H. Schubert[1], John M. Buck[2], and Anthony B. Evanko[3]

Forest managers are constantly seeking to improve methods of reforesting idle timberlands. They have tried many methods of planting and seeding over the years. A recent trial of the rangeland drill, widely used for grass seeding, suggests that it may solve some seeding problems.[4] Preliminary observations of a study installed at Edson Creek on the Shasta-Trinity National Forests in April 1959 look very promising.

The rangeland drill (fig. 1) was specifically designed by the Forest Service for seeding grass on rough rangeland. Available commercial grain drills designed for agricultural use are not built to withstand the hard usage that cannot be avoided on wildland seeding operations. The rangeland drill is custom-fabricated by the Forest Service and is not commercially available at this time. Extensive use has been made of the drill in seeding rehabilitated brush fields for grazing purposes. The drill can be used on most areas in which a tractor can be operated. Stumps and rocks generally do not limit operation of the drill.

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[2] Forester, Division of Timber Management, U. S. Forest Service, Region 5, San Francisco, California.

[3] Forester, Division of Range and Wildlife Management, U. S. Forest Service, Region 5, San Francisco, California.

[4] This technique of direct seeding is reported on a preliminary basis for the information of land managers who may wish to try it without waiting for final results.

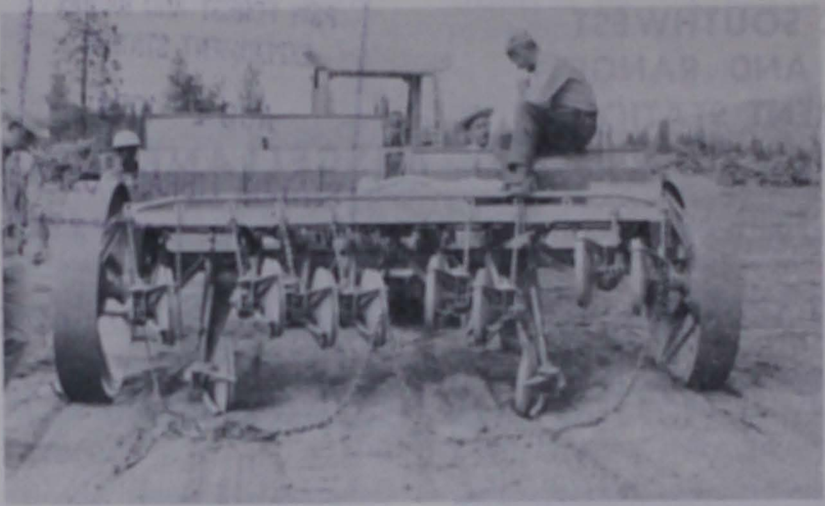
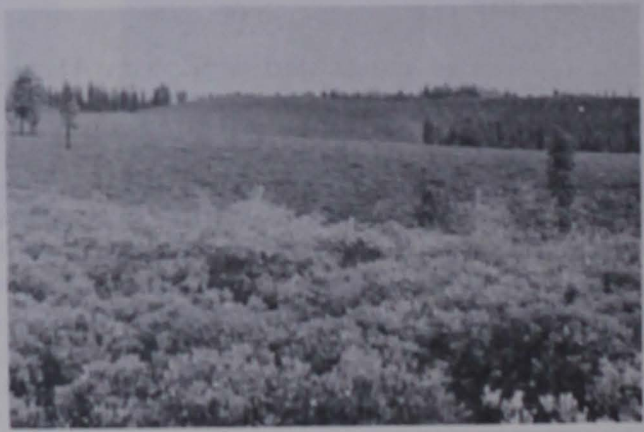


Figure 1. --Rear view of rangeland drill showing two drills used to sow ponderosa pine seed, and log chain used to cover the seed. The machine was designed originally by the Forest Service for sowing seed of forage species.

Figure 2.--Dense brushfield of greenleaf manzanita, snowbrush, and mountain whitethorn.



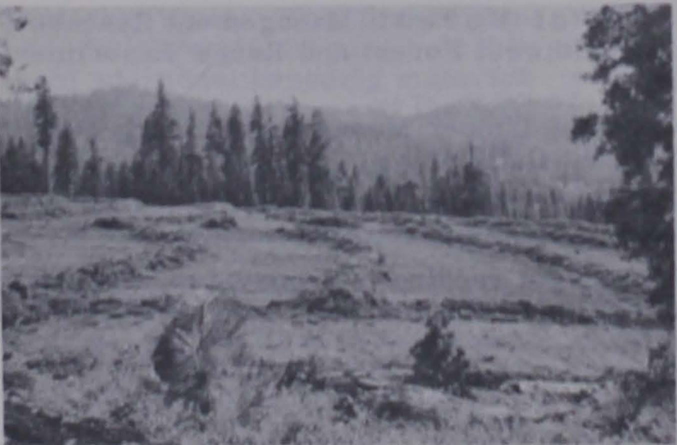


Figure 3. --Brush eradicated with a bulldozer and windrowed on contours.

The study area had burned about 60 years ago. Before then it supported a medium to heavy stand of ponderosa pine and a lesser understory of several species of shrubs. Herbaceous vegetation was an insignificant component of the original cover. After the burn, however, a rather rapid encroachment of greenleaf manzanita, bitter cherry, snowbrush, and mountain whitethorn produced a very dense brush field (fig. 2).

For this study, brushy cover was uprooted with a dozer and windrowed (fig. 3). The primary objective of this site preparation was to remove the root crowns of the shrubs in order to eliminate competition with tree seedlings for soil moisture.

The drill was calibrated, using dry ponderosa pine seed, to sow about one seed per lineal foot of row. All but two seed openings were blocked off to obtain 8 feet spacing between rows (fig. 1). Stratified seed was used. It had to be separated from the stratifying medium (vermiculite) and surface-dried to permit proper passage through the drill's feed assembly.

Seed was sown at a depth of 1/2 to 1 inch. A log chain, fastened to the rear of the drill, was used to cover the seed. The soil was not compacted around the seed by this method of covering. Consequently some drying of soil and seed results if rain does not fall soon after seeding. Installation of press wheels would overcome this disadvantage.

This technique of drill seeding offers possibilities for either spring or fall planting. For most direct seeding techniques, spring seeding is favored because it shortens the period during which the seeds are subject to depredation by rodents. However, single seeds spaced one foot apart in drilled rows may have a greater chance of being missed than either seeds broadcast on the surface or those planted in groups of 5 in spots prepared by hand. As an added safeguard in this study, all seed other than that used to calibrate the drill was treated with endrin and arasan by John Ludeman of the U. S. Fish and Wildlife Service.

The benefits of fall planting which seeding with the rangeland drill may make available are:

1. A substantial prolongation of the planting season and a consequent reduction in the spring work load.

2. Seed does not require vernalization.

3. Soil covering the seeds does not need to be compacted.

Results of the preliminary trial were very favorable and indicated that:

1. The rangeland drill can be regulated to drop ponderosa pine seed at a rate of about one seed per lineal foot of drill row.

2. The seeds had to be nearly dry to feed properly into the tubes--moist seeds and seeds mixed with moist vermiculite clogged the metering device.

3. A heavy chain, fastened to the rear of the drill, adequately covered the seeds.

4. Seed germination was good. A high percentage of germination and survival is not required for satisfactory stocking because the seeds are well distributed and are sown at the rate of about 5,400 per acre.

Some items which will require further study are:

1. Changes in design or operation of the drill which may improve performance.

2. Kinds of areas in which the drill can be used--slope, number and size of stumps, size of area, etc.

3. Is direct seeding with the rangeland drill more effective than seed spotting by hand--how much?

4. How does direct seeding with the rangeland drill compare in cost with hand methods of planting?

5. When is the best time to drill--spring or fall?

6. Can animal damage to conifers be reduced by sowing browse plants between the rows of trees?

7. How much conifer seed will be needed to get adequate stocking?

Answers to these and other questions are expected from a series of large-scale studies planned during the next two years.

alker

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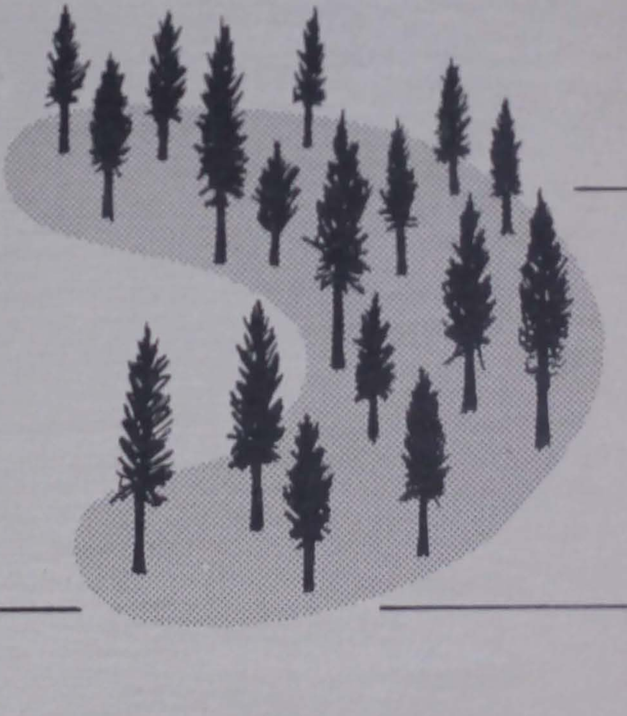
Trees of the Eddy Arboretum

A. R. Liddicoet
F. I. Righter



Miscellaneous Paper 43
January ········ 1960

PACIFIC SOUTHWEST
FOREST AND RANGE
EXPERIMENT STATION

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

TREES OF THE EDDY ARBORETUM

INSTITUTE OF FOREST GENETICS, PLACERVILLE, CALIFORNIA

By

A. R. Liddicoet, Forestry Aid, and F. I. Righter, Forest Geneticist
Division of Forest Genetics Research

Miscellaneous Paper No. 43

January 1960

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION

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TREES OF THE EDDY ARBORETUM

INSTITUTE OF FOREST GENETICS, PLACERVILLE, CALIFORNIA

By A. R. Liddicoet and F. I. Righter[1]

Because genetic diversity is the raw-material of breeding, one of the first concerns of the systematic breeder is to assemble at one convenient place as many as possible of the species and varieties of the genus or genera with which he works. Accordingly, the establishment of some 70 to 80 species of pine at Placerville, California was started shortly after the Eddy Tree Breeding Station, now the Institute of Forest Genetics, was founded in 1925. The arboretum which grew from these early efforts was named in honor of the founder, Mr. James G. Eddy.

This arboretum now contains what probably is the most complete collection of pines in the world, including 72 species, 35 varieties, and 90 different hybrids (F_1 interspecific crosses, backcrosses, 3-way hybrids, and progenies arising from interbreeding among members of the same F_1 cross), as well as some artificially-produced polyploid pines and a few specimens of various other genera of forest-trees. As research has so far been restricted to the pines, there has been no systematic planting of other conifers or angiosperms. Altogether, some 16,000 planted trees occupy 55 acres. The collection includes representatives of ponderosa pine from more than 50 sources, from British Columbia to Mexico and from South Dakota to the Pacific coast.

The area is divided into a main arboretum in which the various species are located and contiguous areas on which provenience, progeny, and hybrid tests are underway. In the main arboretum, the trees, mostly 28 to 30 years of age in 1957, are 15 to 20 feet tall for the slow growing species and up to 80 feet for the faster growing species; trees in the provenience, progeny, and hybrid tests are younger. Thus, the Eddy Arboretum serves as a breeding-laboratory and as a place where students, botanists, foresters, visiting scientists, and laymen can observe and study most of the pines and many hybrids.

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[1] We are indebted to Dr. J. W. Duffield for suggestions regarding revision of the article and to Dr. N. T. Mirov for critical review and suggestions.

To satisfy the numerous requests of visitors and correspondents for information about the arboretum, "Trees in the Eddy Arboretum" was published in 1947.[2] Many hybrids and some species have been added to the arboretum since then, and some species have failed. This revision brings the list of trees up-to-date and presents several features not included in the original publication.

The arboretum is located about half way between Sacramento and the summit of the Sierra Nevada at an average elevation of 2,700 feet. It has a south and southwest aspect. The soil is a deep, Aiken clay-loam. Its location puts the arboretum well above the hot Central Valley but below the colder zones of the Sierra Nevada (for climatological data see appendix).

Some pines have failed at the Institute of Forest Genetics:

Pinus aristata Engelm (bristlecone)--trees probably were not taken care of as well as they should have been.

P. cembra L. (Swiss stone)--trees probably were not taken care of as well as they should have been.

P. insularis Endl. (Luzon)--too cold.

P. merkusii Vriese (Tenasserim)--too cold.

P. occidentalis Swartz (West India)--too cold.

P. oocarpa Schiede (eggcone)--does not do well, too cold. (Perhaps Chihuahua strain would do better.)

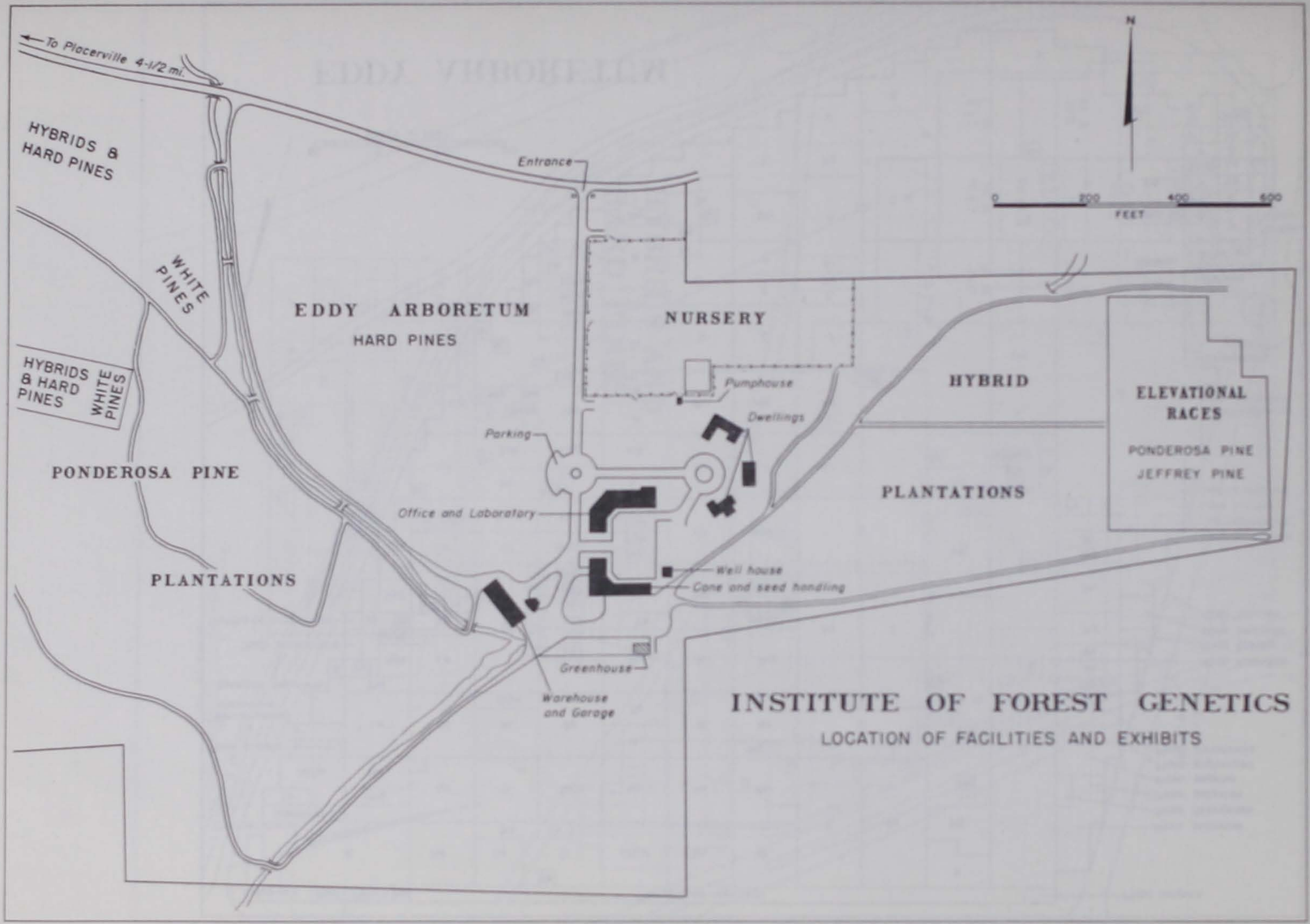
P. parviflora Sieb. & Zucc. (Japanese white)--trees probably were not taken care of as well as they should have been.

P. pinceana Gord. (Pince)--trees probably were not taken care of as well as they should have been.

P. tropicalis More--too cold.

An extension of the Eddy Arboretum for the establishment and maintenance of high elevation, cold climate species which do not do well at the Institute of Forest Genetics is under development at an elevation of 5,000 feet on the Eldorado National Forest. The University of California has made available an area in Strawberry Canyon, Berkeley, for species which are not frost-hardy at the Institute. Plantings were made on both sites in 1958, but a report of species involved will be made only after establishment is assured.

2/ Weidman, R. H. Trees in The Eddy Arboretum, Institute of Forest Genetics, Placerville, California. U. S. Forest Service, Calif. Forest and Range Expt. Sta. Forest Res. Note 53. 8 pp. April 1947.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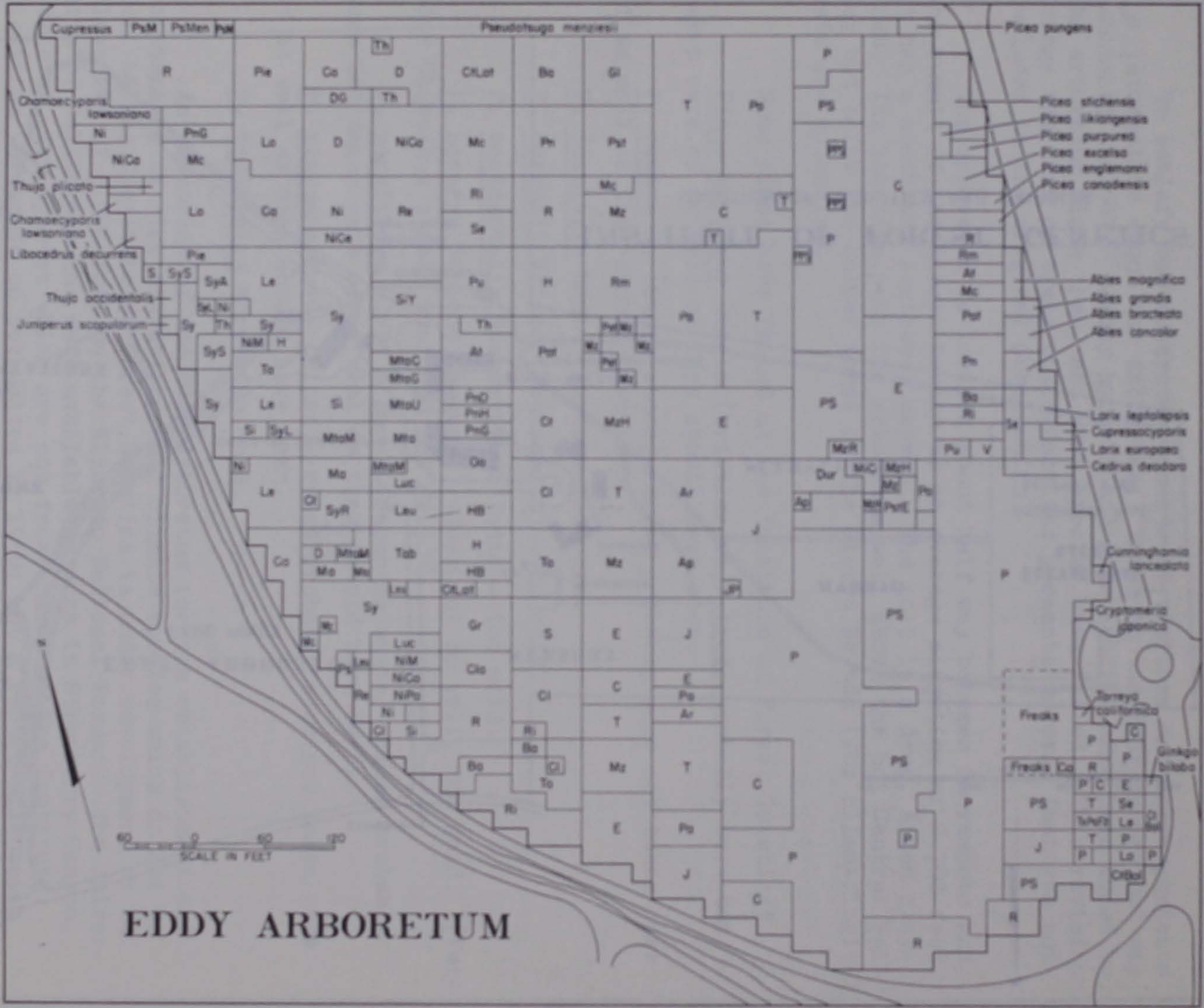
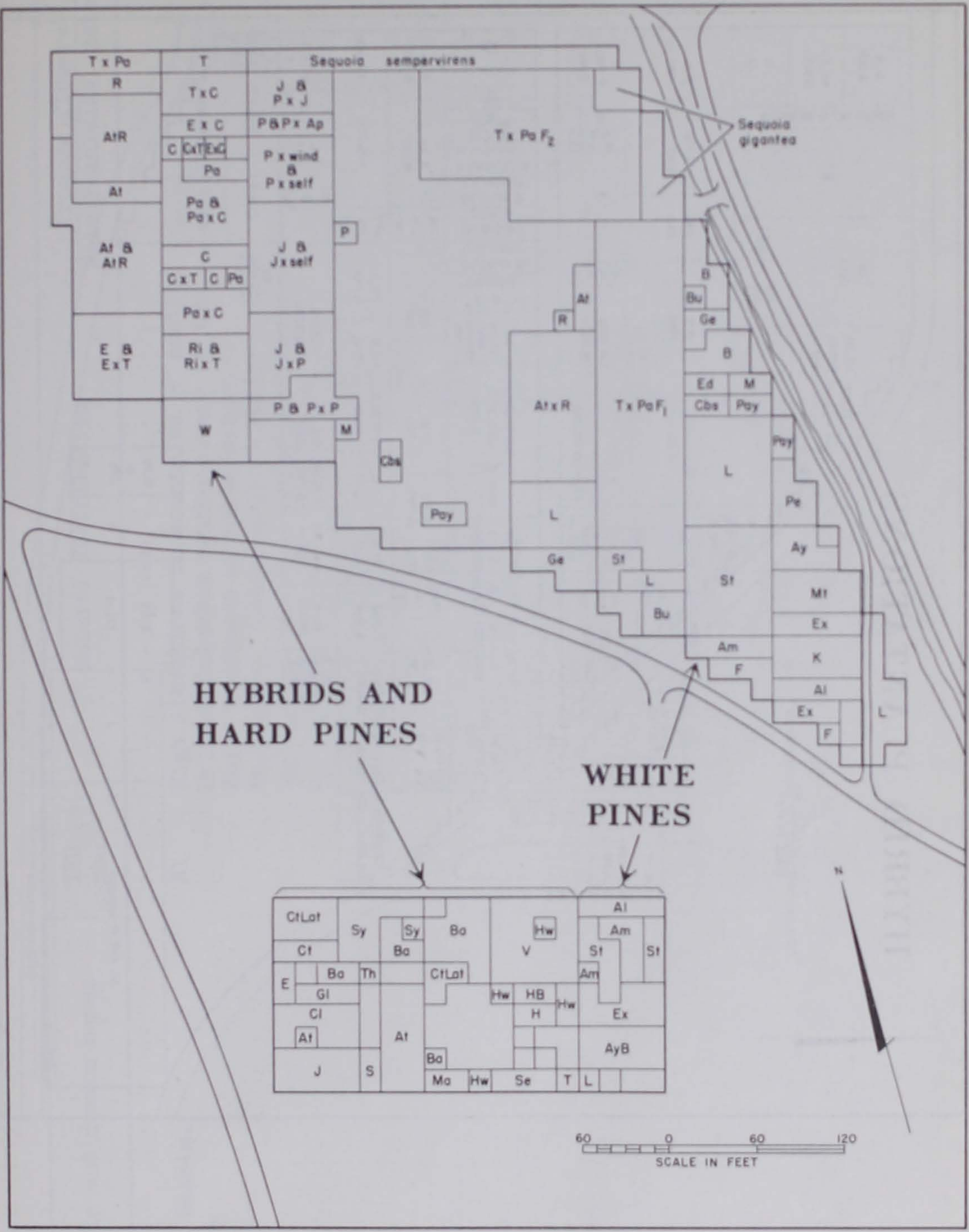
HYBRIDS & HARD PINES
Entrance
WHITE PINES
EDDY ARBORETUM
HARD PINES
NURSERY
Pumphouse
Dwellings
HYBRIDS & HARD PINES
WHITE PINES
HYBRID
ELEVATIONAL RACES
PONDEROSA PINE
JEFFREY PINE
Parking
PONDEROSA PINE
Office and Laboratory
PLANTATIONS
PLANTATIONS
Well house
Cone and seed handling
Greenhouse
Warehouse and Garage

INSTITUTE OF FOREST GENETICS

LOCATION OF FACILITIES AND EXHIBITS


Cupressus
PsM
PsMen
Pseudotsuga menziesii
Picea pungens
Chamaecyparis lawsoniana
Thuja plicata
Chamaecyparis lawsoniana
Libocedrus decurrens
Thuja occidentalis
Juniperus scopulorum
Picea sitchensis
Picea likiangensis
Picea purpurea
Picea excelsa
Picea englemanni
Picea canadensis
Abies magnifica
Abies grandis
Abies bracteata
Abies concolor
Larix leptolepsis
Cupressocyparis
Larix europaea
Cedrus deodara
Cunninghamia lanceolata
Cryptomeria japonica
Torreya californica
Ginkgo biloba
Freaks
N
60 0 60 120
SCALE IN FEET

EDDY ARBORETUM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Sequoia sempervirens
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J & P x J
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E x C
P & P x Ap
C
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ExC
P x wind & P x self
Pa
At
Pa & Pa x C
J & J x self
At & AtR
C
C x T
C
Pa
Pa x C
E & E x T
Ri & Ri x T
J & J x P
P & P x P
W
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P
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Sequoia gigantea
At
R
At x R
T x Pa F1
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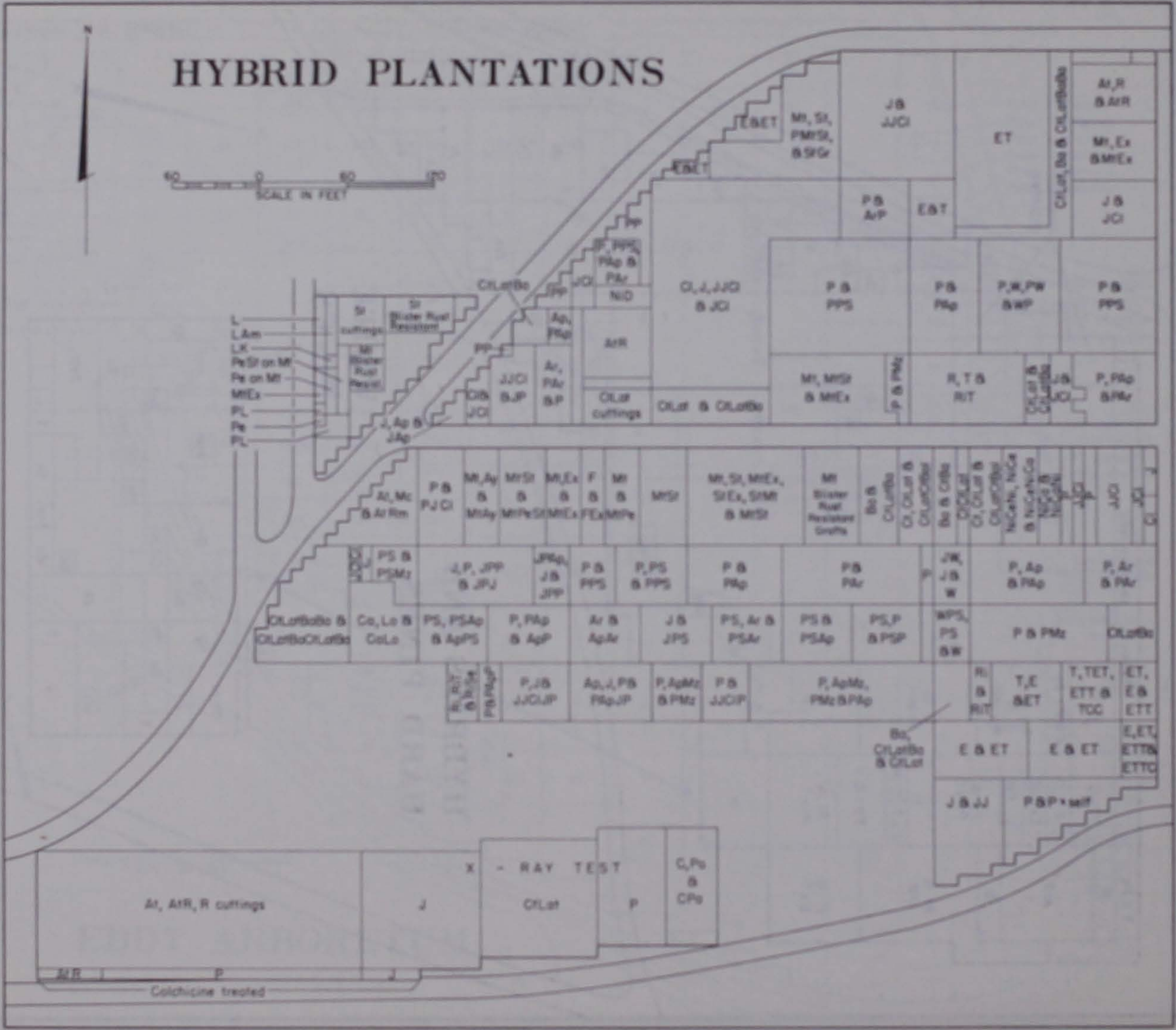
HYBRID PLANTATIONS
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L.K
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Pe on Mt
MtEx
PL
Pe
PL
St cuttings
St Blister Rust Resistant
Mt Blister Rust Resist.
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PP
J, Ap & JAp
E&ET
E&ET
Mt, St, PMtSt, & StGr
J & JJCl
ET
Cf Lat, Bo & CfLatBoBo
Ar, R & ArR
Mt, Ex & MtEx
J & JCl
P & ArP
E&T
PP
P, PPS, PAp & PAr
JCl
NiD
PP
Ap, PAp
ArR
Ar, PAr & P
JJCl & JP
Cl & JCl
Cl, J, JJCl & JCl
P & PPS
P & PAp
P, W, PW & WP
P & PPS
Mt, MtSt & MtEx
P & PMz
R, T & RT
J & JCl
P, PAp & PAr
CfLat cuttings
CfLat & CfLatBo
At, Mc & At Rm
P & PJCl
Mt, Ay & MtAy
MtSt & MtPeSt
Mt, Ex & MtEx
F & FEx
Mt & MtPe
MtSt
Mt, St, MtEx, StEx, StMt & MtSt
Mt Blister Rust Resistant Grafts
Bo & CfLatBo
JJCl
JCl
PS & PSMz
J, P, JPP & JPJ
JPAp, J & JPP
P & PPS
P, PS & PPS
P & PAp
P & PAr
P
JW, J & W
P, Ap & PAp
P, Ar & PAr
CfLatBoBo & CfLatBoCfLatBo
Co, Lo & CoLo
PS, PSAp & ApPS
P, PAp & ApP
Ar & ApAr
J & JPS
PS, Ar & PSAr
PS & PSAp
PS, P & PSP
WPS, PS & W
P & PMz
CfLatBo
P, J & JJCl JP
Ap, J, P & PAp JP
P, ApMz & PMz
P & JJCl P
P, ApMz, PMz & PAp
R & RT
T, E & ET
T, TET, ETT & TOC
ET, E & ETT
Bo, CfLatBo & CfLat
E & ET
E & ET
E, ET, ETT & ETTC
J & JJ
P & P × self
X - RAY TEST
Ar, ArR, R cuttings
J
CfLat
P
C, Ps & CPs
ArR
P
J
Colchicine treated

Scientific and common names	IFG symbol[1]	Natural distribution	Produce flowers[2]		
			Male	Female	Av. date
Pinus					
albicaulis Engelm. Whitebark	Al	High elevations in mountains of central British Columbia southeastward in the Rocky Mountains of northeastern Washington, Idaho, western Montana, and western Wyoming to northern Utah; and southward in the Cascade and Sierra Nevada Mountains to central California. Also in mountains of northeastern Oregon.			
armandi Franch. Armand	Am	Mountains of southern, central, and western China (Yunnan, Kweichow, Szechwan, Hupeh, Kansu, Shansi), and Taiwan (Formosa).	x		5/12
attenuata Lemm. Knobcone	At	Mountains (Cascades) of southwestern Oregon south in coastal ranges of California to San Bernardino Mountains. South in Sierra Nevada of California to Mariposa County. Northern Baja California, Mexico.	x	x	4/15

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[1] Used for convenience on tree-labels, in records, and on maps.

[2] As systematic annual surveys of flower production are not made, flowering may have occurred in some species for which flower production is not indicated. Average date refers to date of pollen-shedding. Female strobili (conelets) attain maximum receptivity at about the same time.

PINES IN THE ARBORETUM

Scientific and common names	IFG symbol	Natural distribution	Produce flowers		
			Male	Female	Av. date
Pinus					
ayacahuite Ehren. Mexican white	Ay	High elevations of southern Mexico (Chiapas, Guerrero, Hidalgo, Oaxaca, Puebla, Tlaxcala, Vera Cruz, and Guatemala; rare in Honduras.	x	x	5/29
ayacahuite var. brachyptera Shaw Mexican white	AyB	Northern Mexico in the States of Chihuahua, Durango, Sinaloa, Sonora, and Zacatecas.			
balfouriana Grev. & Balf. Foxtail	B	High elevations in northwestern California (Siskiyou and Trinity Counties), and southern Sierra Nevada Mountains.			
banksiana Lamb Jack	Ba	Nova Scotia and central Quebec across Canada (Ontario, southern Manitoba, and Saskatchewan, central Alberta) to northern British Columbia and the Yukon and Mackenzie regions. In United States from Maine westward across northern New Hampshire, Vermont, New York, Michigan, Wisconsin, and northeastern Minnesota.	x	x	4/13
brutia Tenore Erectcone Aleppo	Br	Southeastern Europe, southwestern Asia.	x	x	4/20
bungeana Zucc. & Endl. Lacebark	Bu	Mountains of central and northern China (Shansi), Shensi, Hupeh, Hopei, Szechwan.	x	x	5/13

Scientific and common names	IFG symbol	Natural distribution	Produce flowers		
			Male	Female	Av. date
Pinus					
canariensis Smith Canary Island	Ca	Canary Islands, 5,000 to 7,000 feet elevation.	x	x	3/26
caribaea Mor. Caribbean	C	Bahama Islands, West Indies. Atlantic slope of northern Central America (British Honduras, northern Honduras, northeastern Nicaragua).			
cembroides Zucc. Mexican pinyon	Cbs	Mountains of southeastern Arizona, southwestern New Mexico. Widely distributed in Mexico, occurring in Aguascalientes, Baja California, Chihuahua, Coahuila, Durango, Hidalgo, Jalisco, Nuevo Leon, Puebla, Queretaro, San Luis Potosi, Sonora, Tamaulipas, Tlaxcala, and Zacatecas.	x	x	
clausa (Chapin) Vasey Sand	Cla	Florida and west to coastal Alabama.			
contorta Dougl. Some authors recognize two varieties: a coastal form P. contorta var. contorta (Shore Pine) and an inland or mountain form P. contorta var. latifolia Engelm. (Lodgepole Pine).	Ct	Has extraordinary range in latitude (±30°) and altitude (sea level to 11,000 feet). In Canada from Alberta through British Columbia and southeastern Alaska to the Yukon region. In United States, coast of Washington, Oregon, and California to Mendocino County; mountains of northern Washington south in Cascades and Sierra Nevada	x	x	5/12

Scientific and common names	IFG symbol	Natural distribution	Produce flowers		
			Male	Female	Av. date
Pinus contorta Dougl.--cont.		and mountains of southern California to Baja California; Rocky Mountains from northwestern Washington to northeastern Utah and central Colorado; also in Black Hills of South Dakota and Wyoming, and mountains of northwestern Oregon.			
cooperi Blanco Cooper	Co	Durango, Mexico			
cooperi var. ornelasi Blanco	CoO	Durango, Mexico			
coulteri D. Don Coulter	Cl	From Mt. Diablo south in coastal and southern mountains of California to northern Baja California.	x	x	5/20
densiflora Sieb & Zucc. Low elev. Japanese red	D	Mountains of Japan from southern Kyushu to southern Hokkaido. South Korea, East China.	x	x	5/3
densiflora var. globosa Mayr. Japanese globe	DG	Japan	x	x	
durangensis Martinez Durango	Dur	Southern Chihuahua and Durango in Mexico.			
durangensis var. quinquefoliata Martinez	DurQ	Durango, Mexico			

Scientific and common names	IFG symbol	Natural distribution	Produce flowers		
			Male	Female	Av. date
Pinus					
echinata Mill Shortleaf	E	Southeastern Connecticut, southeastern New York, southern New Jersey, eastern Pennsylvania, Delaware, eastern Maryland, eastern Virginia, North Carolina, South Carolina to southern Georgia and west across Alabama, Mississippi, northern Louisiana, Arkansas to eastern Texas and Oklahoma; from northern Arkansas and southern Missouri across western Tennessee, Kentucky, southern Illinois, southern Ohio and western West Virginia to southwestern Pennsylvania.	x	x	5/1
edulis Engelm. Pinyon	Ed	Rocky Mountain regions of Utah, Colorado, Arizona, New Mexico. Trans-Pecos, Texas, extreme northwestern Oklahoma, southwestern Wyoming, southeastern California and northern Baja California.	x	x	
elliottii Engelm. Slash	El	South Atlantic and Gulf coastal plains of the United States from southern South Carolina to central Florida and southeastern Louisiana.	x	x	3/22

PINES IN THE ARBORETUM

Scientific and common names	IFG symbol	Natural distribution	Produce flowers		
			Male	Female	Av. date
Pinus					
engelmannii Carr. Apache	Ap	Mountains of southwestern New Mexico and southeastern Arizona south in Sonora, Chihuahua, Sinaloa, and Durango to Zacatecas in central Mexico. Up to 9,000 feet elevation in Mexico.	x	x	5/10
flexilis James Limber	F	Chiefly Rocky Mountain region from southeastern British Columbia and southern Alberta south in mountains of Montana, Idaho, Nevada, central Sierra Nevada and southern ranges of California east to Trans-Pecos, Texas. Local in northwestern North Dakota, Black Hills of South Dakota, western Nebraska, and northeastern Oregon. Occurs in northeastern Mexico and Nueva Leon.	x	x	5/24
flexilis var. reflexa Engelm. Border limber	F Ref	Mountains of southeastern Arizona and southwestern New Mexico and in Chihuahua and Coahuila, Mexico.			
gerardiana Wall. Gerard	Ge	Northwestern Himalaya Mountains, India, Afghanistan. Baluchistan. Reaching up to 12,000 feet.			

Scientific and common names	IFG symbol	Natural distribution	Produce flowers		
			Male	Female	Av. date
Pinus					
glabra Walt. Spruce	Gl	South Atlantic and Gulf coastal plains of United States: South Carolina to northern Florida west to southeastern Louisiana.	x	x	4/8
greggii Engelm. Gregg	Gr	Sierra Madre Oriental Mountains of Mexico: southern Coahuila and Nueva Leon, southern San Luis Potosi and eastern Hidalgo.	x	x	5/29
griffithii McCell. (Excelsa Wall.) Himalayan	Ex	6,000 to 12,500 feet elevation in the Himalaya Mountains from Nepal to Afghanistan.	x	x	5/16
halepensis Mill. Aleppo	H	Mediterranean region: Portugal to Asia Minor, Algeria and Cyprus - up to 2,000 feet in elevation.	x	x	4/18
halepensis var. pityusa Stev.&Ball Large cone Aleppo	Pt	East coast of Black Sea, Thrace Anatolia, Syria and the Islands of Prinkipo and Thasos.	x	x	
hwangshanensis Hsia	Hw	Southeastern China			
jeffreyi Grev. and Balf. Jeffrey	J	Mountains of southwestern Oregon, southeastward along the Cascade, Sierra Nevada, San Bernardino and San Jacinto Mountains to northern Baja California. Occurs also in Mendocino County, California and in the San Benito Mountains of California.	x	x	5/29

PINES IN THE ARBORETUM

Scientific and common names	IFG symbol	Natural distribution	Produce flowers		
			Male	Female	Av. date
Pinus					
koraiensis Sieb. and Zucc. Korean	K	Amurland, Manchuria, Korea, and local on several mountains of central Japan.			
kwangtungensis	Kw	Southern China, in the mountains of Kwangtung, Kwangsi, Hunan proveniences and the island of Hainan.			
lambertiana Dougl. Sugar	L	Mountains of western Oregon, south in coastal ranges, Sierra Nevada and mountains of southern California to northern Baja California.	x	x	6/1
leiophylla Sehl. & Cham. Smoothleaf	Le	In Mexico from Sonora and Chihuahua to Oaxaca: occurs in Chihuahua, Durango, Jalisco, Mexico, Michoacan, Morelos, Nayarit, Oaxaca, Puebla, Tlaxcala, Valle de Mexico, Vera Cruz, Zacatecas.	x	x	5/20
leiophylla var. chihuahuana Engelm. Chihuahua	LeC	Mountains of southwestern New Mexico and central and southeastern Arizona, and in northern Mexico (Sonora, and Chihuahua south to Durango, Nayarit, Jalisco, and Zacatecas.			

Scientific and common names	IFG symbol	Natural distribution	Produce flowers		
			Male	Female	Av. date
Pinus					
leucodermis Antoine Greybark	Leu	Balkan Peninsula (Bosnia, Hercegovina, Montenegro) and southern Italy. Elevation 4,000 to 5,000 feet.	x	x	5/24
luchuensis Mayr. Luchu	Luc	Ryukyu Islands. (Okinawa)	x		4/12
lumholtzii Rob. & Fern. Lumholtz	Lum	Central Mexico in the states of Aguascalientes, Chihuahua, Durango, Guanajuato, Jalisco, Nayarit, Sinaloa, and Zacatecas.			
massoniana Lamb. Masson: Chinese red	Ma	Southeastern China and along Yangtse River into Szechwan.	x	x	4/12
michoacana var. cornuta Martinez	MiC	Widely distributed in Mexico - states of Chiapas, Durango, Guanajuato, Querrero, Hidalgo, Jalisco, Mexico, Michoacan, Morelos, Nayarit, Nuevo Leon, Oaxaca, Puebla, Vera Cruz, Zacatecas.			
monophylla Torr. & Frem. Singleleaf pinyon	M	Mountains of the Great Basin Region from southern Idaho south to central and east central Arizona and southwest across Nevada to southern California and northern Baja California.	x	x	6/2

PINES IN THE ARBORETUM

Scientific and common names	IFG symbol	Natural distribution	Produce flowers Male	Female	Av. date
Pinus					
montana Mill. Swiss mountain	Mta	Mountains of southern Europe: central Spain to Balkan Mountains.	x	x	5/16
montana var. compacta D.Hill Dwarf mugo	MtaC	Alps to mountains of central Europe and the Balkan Peninsula.	x	x	
montana var. gallica French mountain	MtaG	Mountains of southeastern France.	x	x	5/16
montana var. mughus Willk. Mugo	MtaM	Eastern Alps and mountains of the Balkan states.	x	x	5/16
montana var. uncinata Willk. Large Swiss	MtaU	Pyrenees to western Alps.	x	x	5/14
montezumae Lamb. Montezuma	Mz	Widely distributed in all climatic zones of Mexico. Reported in states of Chiapas, Coahuila, Guerrero, Hidalgo, Jalisco, Mexico, Michoacan, Morelos, Puebla, Tlaxcala, Valle de Mexico, Vera Cruz.	x	x	4/28
montezumae var. hartwegii Lind.	MzH	Cold areas of Mexico, usually at elevations of 10,000 to 12,000 feet. Reported in states of Coahuila, Hidalgo, Tlaxcala and Valle de Mexico.			

Scientific and common names	IFG symbol	Natural distribution	Produce flowers		
			Male	Female	Av. date
Pinus					
montezumae var. rudis Endl.	MzR	Widely distributed in cool areas of Mexico, usually at elevations of 8,000 to 9,000 feet. Reported in states of Coahuila, Hidalgo, Jalisco, Mexico, Michoacan, Nayarit, Nuevo Leon, Oaxaca, Puebla, Tamaulipas, Valle de Mexico, Zacatecas. Also found in Guatemala.			
monticola Dougl. Western white	Mt	Southwestern Alberta to western Montana and northern Idaho, and southern British Columbia south in Cascades and Sierra Nevada mountains to central California.	x	x	5/22
muricata D. Don. Bishop	Mc	A narrow, highly discontinuous strip along the coast from vicinity of Trinidad Head in Humboldt County to La Purissima in Santa Barbara County thence southward in insular California to Guadalupe and Cedros Islands and again on the mainland of Baja California at Pt. San Quentin where it has been described as var. Anthonyi Lem.	x	x	4/20

PINES IN THE ARBORETUM

Scientific and common names	IFG symbol	Natural distribution	Produce flowers		
			Male	Female	Av. date
Pinus					
Nelsoni shaw Nelson	Ne	Limited distribution in northeastern Mexico, occurring on lower slopes (elevation about 7,000 feet) of mountains in Coahuila, Nueva Leon, San Luis Potosi, and Tamaulipas.			
nigra Arnold Austrian	Ni	Mountains of central and southeastern Europe. Very variable species.	x	x	5/9
nigra var. calabrica Schneid Corsican	NiCa	Southern Europe.	x	x	5/19
nigra var. cebennensis Rehder Cevennes	NiCe	Pyrenees Mountains, and Cevennes Mountains in southeastern France.	x	x	5/26
nigra var. mauritanica Mair & Peyer Algerian	NiM	Djurdjura, Algeria, Africa.	x	x	
nigra var. pallasiana Ascher.& Graeb. Crimean	NiPa	Asia Minor, Crimean region.	x	x	
nigra var. salzmannii Dun.	NiS	Pyrenees Mountains, Spain			

PINES IN THE ARBORETUM

Scientific and common names	IFG symbol	Natural distribution	Produce flowers		
			Male	Female	Av. date
Pinus					
oocarpa Schiede Eggcone	Oo	Widely distributed in Mexico, occurring in Chiapas, Chihuahua, Durango, Guerrero, Jalisco, Mexico, Michoacan, Morelos, Nayarit, Oaxaca, Puebla, Sinaloa, Sonora, and Zacatecas, and in Guatemala, Honduras and Nicaragua. (Grows farther south than any other pine in New World, excepting, perhaps P. caribaea.)			
palustris Mill. Longleaf	Pa	Southern Atlantic and Gulf coastal plains of United States, Virginia to central Florida to east Texas.		x	
parviflora Sieb. & Zucc. Japanese white	Pav	Mountains of Japan from Shikoku Island northeastward to Hidaka Mountains of Hokkaido.			
parviflora var. pentaphylla Japanese white	PavP	Japanese islands of Hokkaido and Honshu.			
patula Schl. & Cham. Mexican weeping	Pat	Warm-temperate regions of eastern and central Mexico - in Hidalgo, Mexico, Puebla, Queretaro, Valle de Mexico, and Vera Cruz. Occurring up to 9,000 feet.	x	x	4/15
peuce Griseb. Macedonian	Pe	Mountains of the Balkan Peninsula: Yugoslavia, Macedonia, Bulgaria, and Greece. 5,000 to 6,000 feet.			

PINES IN THE ARBORETUM

Scientific and common names	IFG symbol	Natural distribution	Produce flowers		
			Male	Female	Av. date
Pinus					
pinaster Ait. Maritime	Pn	Coastal regions of western Mediterranean (Portugal, Spain, and Atlas Mountains of Morocco and Algeria); eastward in Europe to Yugoslavia, Greece, and Turkey where it occurs up to 2,800 feet elevation.	x	x	4/16
pinaster var. des landes	PnD	Southwestern France.	x	x	4/1
pinaster var. gigantea	PnG	Mediterranean Region.	x	x	4/17
pinaster var. hamiltonii Gord. Lord Aberdeen	PnH	Mountains near Nice, France.	x	x	4/30
pinea L. Italian stone	Pie	Mediterranean Region from Portugal to Asia Minor. Not commonly found above 2,000 feet.	x	x	5/14
ponderosa Laws. Ponderosa	P	Widely distributed in western North America from British Columbia south in Cascades and Coastal Mountains to central California, and in Sierra Nevada to mountains of southern California and northern Baja California; southwest from British Columbia in Rocky Mountains to southeastern Arizona, Trans-Pecos Texas and in Sonora and Chihuahua to Durango, Mexico; southwestern North Dakota, and western South Dakota; Nebraska.	x	x	5/1

PINES IN THE ARBORETUM

Scientific and common names	IFG symbol	Natural distribution	Produce flowers		
			Male	Female	Av. date
Pinus					
ponderosa var. arizonica (Engelm.) Shaw Arizona	Ar	Mountains of extreme southeastern Arizona and southwestern New Mexico and northern Mexico (Sonora, Chihuahua, Durango, Nuevo Leon, and Tamaulipas.)	x	x	4/28
ponderosa var. arizonica stormiae	ArS	Northeastern Mexico in the states of Coahuila and Nuevo Leon.			
ponderosa var. scopulorum Engelm. Rocky Mountain ponderosa	PS	Eastern Nevada, Utah, western Colorado and east of the Continental Divide.	x	x	4/27
pseudostrobus Lindl. False Weymouth	Pst	Widely distributed in Mexico (states of Chiapas, Jalisco, Mexico, Michoacan, Nuevo Leon, Puebla, Tamaulipas, Valle de Mexico) and extending south to Guatemala, Honduras, and Nicaragua, up to 10,000 feet elevation.			
pseudostrobus var. estevezi Martinez	PstE	Northeastern Mexico in the states of Coahuila and Nuevo Leon.			
pseudostrobus var. protuberans Martinez	PstP	Central Mexico in the states of Mexico, Michoacan and Valle de Mexico.			

PINES IN THE ARBORETUM

Scientific and common names	IFG symbol	Natural distribution	Produce flowers		
			Male	Female	Av. date
Pinus					
pungens Lamb. Table Mountain	Pu	Mountains of central Pennsylvania southwest in western Maryland, Virginia, North Carolina, South Carolina, and eastern West Virginia, Kentucky, Tennessee to northern Georgia. Local in New Jersey.	x	x	4/10
quadrifolia Parl. Parry pinyon	Pay	Local in Riverside and San Diego counties, California, and in northern Baja California.	x	x	6/9
radiata D. Don Monterey	R	Coast of central California (Santa Cruz, Monterey, and San Luis Obispo counties) and Santa Cruz Islands, Santa Rosa Islands, and Guadalupe Island off coast of Baja California.	x	x	3/3
resinosa Red	Re	Newfoundland and Quebec south to southeastern Pennsylvania northwest across Pennsylvania northwest tip of Ohio; northern Michigan; Wisconsin, eastern and northern Minnesota to southeastern Manitoba and east to Ontario; local in West Virginia.	x	x	4/25

Scientific and common names	IFG symbol	Natural distribution	Produce flowers		
			Male	Female	Av. date
Pinus					
rigida Mill. Pitch	Ri	Central Maine to northern coast of Georgia including New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, West Virginia, North Carolina, South Carolina, and eastern parts of Tennessee, Kentucky, and Ohio.	x	x	4/21
roxburghii Sarg. Chir	Lo	Himalaya Mountains from Bhutan to Afghanistan. Mostly in foothills but extends up to 7,000 feet.	x	x	3/29
sabiniana Dougl. Digger	S	Lower slopes of mountains surrounding Central Valley of California.	x	x	4/24
serotina Michx. Pond	Se	Atlantic and Gulf Coastal Plains of the United States from southern New Jersey to northern Florida and northwest to western Florida and central Alabama.	x	x	4/22
sinensis Lamb. (tabulaeformis Carr.) Chinese	Si	Sub-alpine elevations in mountains of central and western China and at lower levels in northern China and Korea. (Very variable.)	x	x	4/26
strobus L. Eastern white	St	From Newfoundland and Gaspe' Peninsula of Quebec south to northern Georgia, and west to southeastern Manitoba; south to southeastern Minnesota and eastern Iowa and east to northeastern Ohio.	x	x	5/16

PINES IN THE ARBORETUM

Scientific and common names	IFG symbol	Natural distribution	Produce flowers		
			Male	Female	Av. date
Pinus					
strobus var. chiapensis Martinez	StC	Southern Mexican states of Chiapas, Guerrero, Oaxaca, Puebla, and Vera Cruz. Also found in Guatemala where it forms extensive forests.			
sylvestris L. Scotch	Sy	Most widely distributed pine. Scotland, throughout Europe and western and northern Asia.	x	x	5/4
sylvestris var. argentea Steven. Silver Scotch	SyA	Caucasus Mountains.	x	x	5/3
sylvestris var. lapponica Fries Lapland	SyL	Northern Europe, Lapland	x	x	
sylvestris var. rigensis Loud. Riga	SyR	Vicinity of Riga in Latvia.	x	x	5/2
tabulaeformis Carr. (sinensis Lamb.) Chinese	Tab	Northern to central and western China. (Very variable.)	x	x	4/24
taeda L. Loblolly	T	Atlantic coastal plain and Piedmont from southern New Jersey to central Florida and west to eastern Texas, southeastern Oklahoma, southeastern Arkansas, and southern Tennessee.	x	x	4/5
taiwanensis Hayata Formosa	Ta	Formosa		x	4/28

Scientific and common names	IFG symbol	Natural distribution	Produce flowers		
			Male	Female	Av. date
Pinus					
teocote Schl. & Cham. Aztec	Te	Probably the most widely distributed pine in Mexico. Not reported in states of Aguascalientes, Baja California, and Chihuahua.			
thunbergi Parl. Japanese black	Th	A maritime species, growing in Japan and the islands of Quelpart and Ooryöng off the coast of Korea.	x	x	4/19
torreyana Parry Torrey	To	Small area on coast north of San Diego, California and on Santa Rosa Island.	x	x	3/17
virginiana Mill. Virginia, Scrub	V	Southeastern New York southwest to southeastern Illinois, south to central Alabama, and east to northern part of the Georgia coast.	x	x	4/23
washoensis Mason & Stockwell Washoe	W	High elevations in southwestern Washoe County, Nevada. (Mt. Rose, north of Lake Tahoe.)		x	
yunnanensis Franch. Yunnan	SiY	Southwestern China (Yunnan and Szechwan).	x	x	4/19

PINE HYBRIDS IN THE ARBORETUM

Scientific and common names	IFG symbol	Produce flowers		
		Male	Female	Av. date
Pinus:				
X attenuradiata Knobcone x Monterey	AtR	x	x	3/30
X attenuradiata x X attenuradiata (Knobcone x Monterey) x (Knobcone x Monterey)	AtR$_{F_2}$	x	x	3/30
X attenuradiata x attenuata (Knobcone x Monterey) x knobcone	AtR,At			
X attenuradiata x radiata (Knobcone x Monterey) x Monterey	AtR,R			
attenuata x X attenuradiata Knobcone x (knobcone x Monterey)	At,AtR	x	x	4/21
attenuata x muricata (Santa Cruz variant of P. muricata) Knobcone x Bishop	AtMc	x	x	3/27
canariensis x roxburghii Canary x chir	CaLo	x		
contorta x banksiana Shore x jack	CtBa	x	x	
contorta x contorta var. murrayana Shore x lodgepole	CtMy	x	x	
echinata x elliottii Shortleaf x slash	EC	x	x	4/3
echinata x (echinata x elliottii) Shortleaf x (shortleaf x slash)	E,EC			
echinata x rigida Shortleaf x pitch	ERi	x	x	

PINE HYBRIDS IN THE ARBORETUM

Scientific and common names	IFG symbol	Produce flowers		
		Male	Female	Av. date
Pinus:				
echinata x taeda Shortleaf x loblolly	ET	x	x	4/18
(echinata x taeda) x (echinata x elliottii) (Shortleaf x loblolly) x (shortleaf x slash)	ET,EC		x	
(echinata x taeda) x (rigida x taeda) (Shortleaf x loblolly) x (pitch x loblolly)	ET,RiT		x	
(echinata x taeda) x taeda (Shortleaf x loblolly) x loblolly	ET,T			
(echinata x taeda) x (taeda x elliottii) (Shortleaf x loblolly) x (loblolly x slash)	ET,TC			
elliottii x palustris Slash x longleaf	CPa			
elliottii x taeda Slash x loblolly	CT	x	x	
engelmannii x (jeffreyi x ponderosa) Apache x (Jeffrey x ponderosa)	Ap,JP			
engelmannii x montezumae Apache x Montezuma	ApMz			
engelmannii x ponderosa Apache x ponderosa	ApP			
engelmannii x ponderosa var. arizonica Apache x Arizona	ApAr		x	
engelmannii x ponderosa var. scopulorum Apache x Rocky Mt. ponderosa	ApPS			

PINE HYBRIDS IN THE ARBORETUM

Scientific and common names	IFG symbol	Produce flowers		
		Male	Female	Av. date
Pinus:				
flexilis x griffithii Limber x Himalayan	FEx	x	x	5/24
jeffreyi x coulteri Jeffrey x Coulter	JCl	x	x	
jeffreyi x (jeffreyi x coulteri--natural hybrid) Jeffrey x (Jeffrey x Coulter--natural hybrid)	J,JCl	x	x	
(jeffreyi x coulteri--natural) x wind (Jeffrey x coulter--natural) x wind		x	x	
(jeffreyi x coulteri--natural) x coulteri (Jeffrey x Coulter--natural) x Coulter	JCl,Cl			
[jeffreyi x (jeffreyi x coulteri--natural)] x (jeffreyi x ponderosa) [Jeffrey x (Jeffrey x Coulter--natural)] x (Jeffrey x ponderosa)	JJCl,JP			
[jeffreyi x (jeffreyi x coulteri--natural)] x ponderosa [Jeffrey x (Jeffrey x Coulter--natural)] x ponderosa	JJCl,P			
jeffreyi x montezumae Jeffrey x Montezuma	JMz			
jeffreyi x ponderosa Jeffrey x ponderosa	JP	x	x	
jeffreyi x ponderosa var. scopulorum Jeffrey x Rocky Mt. ponderosa	JPS		x	

PINE HYBRIDS IN THE ARBORETUM

Scientific and common names	IFG symbol	Produce flowers		
		Male	Female	Av. date
Pinus:				
(jeffreyi x ponderosa) x engelmannii (Jeffrey x ponderosa) x Apache	JP,Ap		x	
(jeffreyi x ponderosa) x jeffreyi (Jeffrey x ponderosa) x Jeffrey	JP,J		x	
(jeffreyi x ponderosa) x ponderosa (Jeffrey x ponderosa) x ponderosa	JP,P			
jeffrey x washoensis Jeffrey x Washoe	JW			
lambertiana x armandi Sugar x Armand	LAm			
lambertiana x Koraiensis Sugar x Korean	LK			
monticola x ayacahuite Western white x Mexican white	MtAy			
monticola x flexilis Western white x limber	MtF			
monticola x griffithii Western white x Himalayan	MtEx	x	x	
monticola x peuce Western white x Macedonian	MtPe		x	
monticola x (peuce x strobus) Western white x (Macedonian x eastern white)	Mt,PeSt		x	
monticola x strobus Western white x eastern white	MtSt	x	x	

PINE HYBRIDS IN THE ARBORETUM

Scientific and common names	IFG symbol	Produce flowers		
		Male	Female	Av. date
Pinus:				
X murraybanksiana Lodgepole x jack	MyBa	x	x	4/23
X murraybanksiana x banksiana (Lodgepole x jack) x jack	MyBa,Ba	x	x	
X murraybanksiana x wind (assumed to be X murraybanksiana) (Lodgepole x jack) x Lodgepole x jack-assumed)	MyBa$_{F_2}$	x	x	
nigra x densiflora Austrian x Japanese red	NiD			
nigra x resinosa Austrian x red	NiRe			
nigra var. calabrica x nigra Corsican x Austrian	NiCa,Ni	x	x	
nigra var. calabrica x resinosa Corsican x red	NiCa,Re			
nigra var. calabrica x thunbergi Corsican x Japanese black	NiCa,Th		x	
nigra var. cebennensis x nigra Cevennes x Austrian	NiCe,Ni	x	x	
nigra var. cebennensis x nigra var. calabrica Cevennes x Corsican	NiCe,NiCa	x	x	
palustris x elliottii Longleaf x slash	PaC			
patula x greggi Mexican weeping x Gregg	PatGr			

PINE HYBRIDS IN THE ARBORETUM

Scientific and common names	IFG symbol	Produce flowers		
		Male	Female	Av. date
Pinus:				
ponderosa x engelmannii Ponderosa x Apache	PAp	x	x	5/20
(ponderosa x engelmannii) x engelmannii (Ponderosa x Apache) x Apache	PAp,Ap			
(ponderosa x engelmannii) x (jeffreyi x ponderosa) (Ponderosa x Apache) x (Jeffrey x ponderosa)	PAp,JP			
(ponderosa x engelmannii) x montezumae (Ponderosa x Apache) x Montezuma	PAp,Mz		x	
(ponderosa x engelmannii) x ponderosa (Ponderosa x Apache) x ponderosa	PAp,P			
(ponderosa x engelmannii) x ponderosa var. arizonica (Ponderosa x Apache) x Arizona	PAp,Ar			
ponderosa x jeffreyi Ponderosa x Jeffrey	PJ			
ponderosa x (jeffreyi x coulteri-natural) Ponderosa x (Jeffrey x Coulter)	P,JCl			
ponderosa x montezumae Ponderosa x Montezuma	PMz			
ponderosa x ponderosa var. arizonica Ponderosa x Arizona	PAr			
ponderosa x ponderosa var. scopulorum Ponderosa x Rocky Mountain ponderosa	PPS			

PINE HYBRIDS IN THE ARBORETUM

Scientific and common names	IFG symbol	Produce flowers		
		Male	Female	Av. date
Pinus:				
ponderosa x washoensis Ponderosa x Washoe	PW			
ponderosa var. arizonica x ponderosa Arizona x ponderosa	ArP			
ponderosa var. scopulorum x engelmannii Rocky Mountain ponderosa x Apache	PSAp			
ponderosa var. scopulorum x montezumae Rocky Mountain ponderosa x Montezuma	PSMz			
ponderosa var. scopulorum x ponderosa Rocky Mountain ponderosa x ponderosa	PS,P			
ponderosa var. scopulorum x ponderosa var. arizonica Rocky Mountain ponderosa x Arizona	PSAr			
pungens x echinata Table Mountain x shortleaf	PuE			
pungens x rigida Table Mountain x pitch	PuRi			
rigida x echinata Pitch x shortleaf	RiE			
rigida x serotina Pitch x pond	RiSe		x	
rigida x taeda Pitch x loblolly	RiT	x	x	4/11

PINE HYBRIDS IN THE ARBORETUM

Scientific and common names	IFG symbol	Produce flowers		
		Male	Female	Av. date
Pinus:				
(rigida x taeda) x (echinata x taeda) (Pitch x loblolly) x (shortleaf x loblolly)	RiT,ET			
(rigida x taeda) x glabra (Pitch x loblolly) x spruce	RiT,Gl			
X sondereggeri - natural Longleaf x loblolly	Son	x	x	3/22
strobus x griffithii Eastern white x Himalayan	StEx	x	x	5/11
strobus x monticola Eastern white x western white	StMt	x	x	
taeda x elliottii Loblolly x slash	TC	x	x	4/3
taeda x (echinata x taeda) Loblolly x (shortleaf x loblolly)	T,ET			
(taeda x elliottii) x elliottii (Loblolly x slash) x slash	TC,C			
virginiana x clausa Virginia x sand	VCla			
washoensis x ponderosa Washoe x ponderosa	WP		x	
washoensis x ponderosa var. scopulorum Washoe x Rocky Mountain ponderosa	WPS			

TAXADS AND CONIFERS OTHER THAN PINES GROWING IN THE EDDY ARBORETUM, 1957

Scientific and common names	Native range
Abies concolor (Gord. & Glend.) Hoopes White fir	Western North America
Abies grandis (Dougl.) Lindl. Grand fir	Western North America
Abies magnifica A. Murr. Red fir	California and Oregon
Abies religiosa Schl. & Cham. Sacred fir	Mexico and Guatemala
Abies venusta (Dougl.) K. Koch Bristlecone fir, Santa Lucia fir	Santa Lucia Mountains, California
Cedrus deodara Loud. Deodar cedar	Himalaya Mountains
Chamaecyparis lawsoniana (A. Murr.) Parl. Port-Orford-cedar	Southwest Oregon to northwest California
Cryptomeria japonica D. Don Cryptomeria	Japan
Cunninghamia lanceolata Hook. Chinese fir	China
X Cupressocyparis Leylandii Dallim. and Jacks. Leyland cypress (Chamaecyparis nootkatensis x Cupressus macrocarpa)--natural hybrid (possibly a mutant)	Received from Winchester, England
Cupressus arizonica var. bonita Lemm. Arizona cypress	Arizona
Cupressus Goveniana Gord. Gowen cypress	California

TAXADS AND CONIFERS OTHER THAN PINES GROWING IN THE EDDY ARBORETUM, 1957

Scientific and common names	Native range
Cupressus guadalupensis S. Watson Guadalupe cypress	Mexico
Cupressus lusitanica Mill. Mexican cypress	Mexico and Guatemala
Cupressus macnabiana A. Murr. McNab cypress	Oregon and California
Cupressus nevadensis Abrams. Piute cypress	California
Cupressus sargentii Jeps. Sargent cypress	California
Cupressus sempervirens L. Italian cypress	Mediterranean Region
Ginkgo biloba Kaempfer Ginkgo	China
Juniperus cedrus Webb & Barth. Canary Island juniper	Canary Islands
Juniperus chinensis var. japonica Lav. Japanese juniper	Japan
Juniperus chinensis var. pfitzeriana Spaeth Pfitzer juniper	Horticultural variety
Juniperus horizontalis Moench. Creeping juniper	Northern North America
Juniperus occidentalis Hook. Western juniper	California to British Columbia
Juniperus sabina L. Savin juniper	Europe
Juniperus scopulorum Sarg. Rocky Mountain juniper	Rocky Mountains

TAXADS AND CONIFERS OTHER THAN PINES GROWING IN THE EDDY ARBORETUM, 1957

Scientific and common names	Native range
Juniperus virginiana L. Eastern redcedar	Eastern North America
Larix europaea De Candolle (*L. decidua* Mill.) European larch	Europe and Siberia
Larix leptolepis Sieb. and Zucc. (*L. Kaempferi* Sarg.) Japanese larch	Japan
Libocedrus decurrens Torr. Incense-cedar	California and Oregon
Metasequoia glyptostroboides Hu and Cheng Dawn redwood	China
Picea canadensis (Mill.) B.S.P. (*P. glauca* Voss) White spruce	Northern North America
Picea Engelmanni Parry Engelmann spruce	Western North America
Picea excelsa Link. (p. abies Karst) Norway spruce	Northern Europe
Picea likiangensis Pritzel Likiang spruce	Western China
Picea mariana (Mill.) B.S.P. Black spruce	Northern North America
Picea pungens Engelm. Blue spruce	Colorado to Mexico
Picea purpurea Mast. (erroneously labeled *Picea Delavayi*) Purple cone spruce	Western China
Picea sitchensis Carr. Sitka spruce	Northern California to Alaska

TAXADS AND CONIFERS OTHER THAN PINES GROWING IN THE EDDY ARBORETUM, 1957

Scientific and common names	Native range
Pseudotsuga macrocarpa (Vasey)Mary. Bigcone Douglas-fir	Southern California
Pseudotsuga menziesii (Mirb.)Franco Douglas-fir	British Columbia to Mexico
Pseudotsuga menziesii var. glauca (Beisen)Franco Rocky Mountain Douglas-fir	Rocky Mountains
Pseudotsuga Wilsoniana Hayata	Formosa
Sciadopitys verticillata Sieb. and Zucc. Umbrella pine	Japan
Sequoia gigantea Decaisne Giant Sequoia	California
Sequoia sempervirens Endl. Redwood	California
Taxus brevifolia Nutt. Pacific yew	Western North America
Taxus baccata var. fastigiata Loud. Irish yew	Europe
Thuja occidentalis L. Northern white-cedar	Eastern North America
Thuja orientalis L. Oriental arborvitae	Northeast China and Korea
Thuja plicata D. Don Western redcedar	California to Alaska
Torreya californica Torr. California torreya	California

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APPENDIX A

CLIMATOLOGICAL DATA--EDDY ARBORETUM, INSTITUTE OF FOREST GENETICS

Except for temperature data, the climatological data which follow are for the period 1929-1957 inclusive; temperature data for the period 1938-1943 inclusive are missing.

Significant Averages

Annual temperature	57.2° F.
Daily maximum temperatures	67.6° F.
Daily maximum temperature for July	88.7° F.
Daily minimum temperature	46.7° F.
Daily minimum temperature for January and February	33.9 and 35.4° F.
Date of first fall min. of 32° or lower	Oct. 18, 1949
Date of last spring min. of 32° or lower	May 10, 1933
Number of days between dates of 32° or lower	240 days
Annual precipitation (for period July 1929-July 1957)	39.07 inches
Annual snowfall	19.9 inches
Annual evaporation (for years 1949 to 1957 inclusive)	61.27 "
Daily evaporation	0.167 "
Wind speed 18 feet above ground (for years 1949 to 1957 inclusove)	3.51 M.P.H.

Highest Temperatures

	Annual		Monthly		
	°F.	Year	°F.	Year	Month
Average maximum	70.4	1934	96.0	1931	July
Average minimum	50.1	1934	70.3	1931	July
Average	60.3	1934	83.2	1931	July
Highest temperature of record	107.4	July 29, 1936			

Lowest Temperatures

	Annual		Monthly		
	°F.	Year	°F.	Year	Month
Average maximum	64.4	1948	38.3	1937	Jan.
Average minimum	44.4	1948	25.0	1937	Jan.
Average	54.4	1948	31.7	1937	Jan.

Lowest temperature of record 11.7° F. January 20, 1937.

Early Fall and Late Spring Freezing Temperatures

Earliest date of a 32° temperature in the fall	October 18, 1949
Latest date of a 32° temperature in the spring	May 10, 1933
Shortest period between a spring and fall temp. of 32°	189 days 1930
Longest period between a spring and fall temp. of 32°	328 days 1943

Precipitation

Greatest annual	56.88 inches, Season 1950-51
Least annual	23.38 inches, Season 1930-31
Greatest monthly	16.15 inches, January 1940
Least monthly	0.00 inches, June, July, and Aug. several years

Greatest 24 hr. period, 3.78 inches 1/21/43 (Nov. 18, 19 & 20th weekend, 1950 - 9.56 inches)

Greatest annual snowfall	59.0 inches, season 1948-49 and 1951-52
Greatest monthly snowfall	41.3 inches, January 1933
Greatest 24 hr. snowfall	16.0 inches, January 3, 1946
Greatest depth on the ground	36.0 inches, January 1937

Several seasons with no snowfall.

APPENDIX B
SOME COMMON FOREST TREES NATIVE TO THE LOCALITY OF THE INSTITUTE OF FOREST GENETICS

Scientific and common names

Abies concolor (Gord. & Glend.) Lindl.	white fir
Acer macrophyllum Pursh.	big-leaved maple
Aesculus Californica (Spach) Nutt.	California buckeye
Arbutus menziesii Pursh.	madrone
Libocedrus decurrens Torr.	incense cedar
Photinia arbutifolia Lindl.	toyon
Pinus attenuata Lemm.	knobcone pine
Pinus lambertiana Dougl.	sugar pine
Pinus ponderosa Laws.	ponderosa pine
Pinus sabiniana Dougl.	digger pine
Populus fremontii	
Pseudotsuga menziesii (Mirb.) Franco	Douglas fir
Quercus chrysolepis Liebm.	canyon live oak
Quercus douglasi Hook. & Arn.	blue oak
Quercus kelloggii Newb.	California black oak
Quercus lobata Nee	valley white oak
Quercus x moreha Kellogg	
Quercus wislizenii A. DC.	interior live oak
Rhamnus purshiana DC.	coffee berry
Sambuscus glauca Nutt.	elderberry (blue)

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No. 44 February 1960

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A TRIAL OF DIRECT CONTROL OF PINE ENGRAVER BEETLES ON A SMALL LOGGING UNIT

By Willard L. Jackson, Forester
Division of Forest Management Research

Laboratory tests and small-scale field trials have shown the insecticide lindane to be highly toxic to pine engraver beetles. 1/ On the basis of that information, the insecticide was applied to fresh logging slash heavily infested with pine engraver beetles at Challenge Experimental Forest in 1959. Costs were reasonable and no insurmountable problems were encountered.

1959 A GOOD YEAR FOR PINE ENGRAVERS

The winter of 1958-1959 was abnormally dry in California. Warm weather continued later in the fall and began earlier in the spring than usual. Spring rains were few and far between. These conditions made 1959 the worst in many years in terms of potential bark beetle damage to ponderosa pine, especially at the lower elevations.

Experimental cutting operations were begun March 31, 1959, on the Challenge Experimental Forest (average elevation 2,700 feet). Logging of about 39 acres of 90-year old young-growth was completed May 20, and large amounts of fresh slash were readily available for the unusually large overwintering bark beetle population to attack.

We were aware of the potential insect problem at Challenge, thanks to timely warnings from Station entomologists. 2/ Our normal precautions were intensified. Trees were utilized to 9 inches top

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1/ Lyon, R. L. Lindane--a better insecticide for pine engraver beetles. California Forest and Range Expt. Sta. Misc. Paper 29, 2 pp., illus.

2/ Anonymous. Timber or Snags in 1959? Pacific Southwest Forest and Range Expt. Sta. Misc. Paper 34, 4 pp., illus.

diameter inside bark, at most, and many to a 6-inch top. Branches were lopped from the remaining tops to expose the boles to direct sunlight. Any lopped pine branches which fell on the remaining trunk were thrown off. Once logging was completed, tops which had been rolled so that projecting limbs were shading the trunks were re-lopped.

In spite of all precautions, evidence of heavy insect activity in the slash became noticeable in early June 1959. In order to assess the potential danger of this activity, Station entomologist Ralph C. Hall inspected the 1959 logging area. He wrote: [3]

"Several portions of the 1959 spring logging area were examined. These ranged from a very lightly cut area to areas where the cut had been relatively heavy. In the lightly cut area on the east the majority of the trees cut were white fir and Douglas-fir so there was a relatively small amount of pine slash present. However, all the pine slash observed had been heavily attacked by the California five-spined engraver, and prolific broods were being produced. This was true even in the lopped tops because of the fact that very little direct sun penetrated to this material.

"In the heavier cutting on the west there was a high concentration of pine slash. This was also heavily infested, and heavy broods were successfully established. Lopping had also been done in this area but much of it had been ineffective from the standpoint of discouraging engraver beetle attacks. This was because of disturbances in skidding where lopped tops frequently had become shaded with miscellaneous logging debris.

"Brood stages varied mostly from small larvae to pupae and only one sample of about 50 taken contained callow adults. Both sugar pine and ponderosa pine slash appeared to be equally attacked.

" . . . A similar inspection of the 1958 logging areas (was made) about one year ago. At that time pine engraver attacks were generally light. Some tops were observed with no attacks at all. In contrast, in 1959 not a single top was examined which did not have heavy successful broods."

DIRECT CONTROL MEASURES TAKEN

The most promising direct control method appeared to be to spray with the residual type insecticide lindane. Speed was important, since the insecticide would have to be applied before adult insects emerged from the slash. Following instructions published by Station entomologists, [4] we bought lindane and kerosene and started spraying on June 29, 1959. A 3-man crew completed the job in 4 days using 5-gallon, hand-pressurized backpack sprayers (fig. 1).

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[3] Correspondence designated RX-PSW-INSECT SURVEY PROGRAM, General, Detection Report No. 223, Ground Appraisal, June 1959.

Ponderosa and sugar pine tops and large limbs were sprayed on the entire 1959 cutting area. Large piles of slash and trash which had built up along skid trails and near landings were sprayed 100 percent in the hope of contacting any beetles emerging from tops buried within the piles. In the lightly cut compartment, Douglas-fir tops were also sprayed, since Hall had found Douglas-fir engraver beetles in several of the samples he examined.

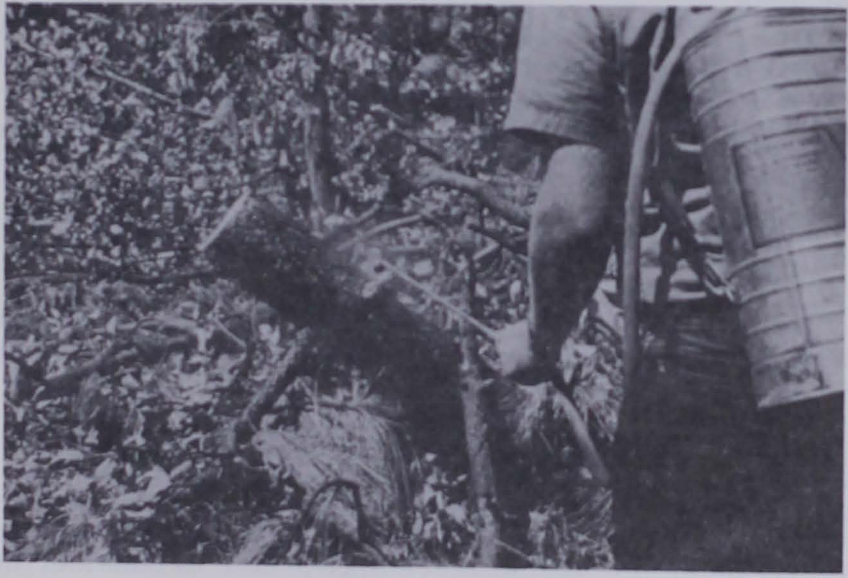

Figure 1.--Spraying ponderosa pine top with lindane insecticide. Despite close utilization and top-lopping, this small top was infested with heavy broods of pine engravers.

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[4] Lyon, Robert L. Directions for using lindane sprays to control pine engravers. Pacific Southwest Forest and Range Expt. Sta. Misc. Paper 33, 5 pp.

AREA TREATED

The 39-acre area treated is generally flat, but has several small draws. It is readily accessible from a main logging road and a spur road. The greatest distance the insecticide had to be carried from a road was about 264 yards, and the average distance was about 110 yards. A dense hardwood understory contained mostly tanoak and madrone, with scattered large California black oaks. Many hardwood stems were knocked down during falling and logging, thus adding to the debris on the ground and making foot travel through the area more difficult.

On the three heavily-cut compartments (29 acres), the original stand volume averaged 43,000 board feet per acre. About 34,000 board feet per acre was cut, including about 20,000 of pine. The total number of pine trees cut (and thus, tops requiring treatment) was 501, or 17.3 per acre.

On the lightly-cut compartment (10.4 acres), the original stand volume was 40,000 board feet per acre. About 11,000 board feet per acre was cut, including 8,700 of pine and Douglas-fir. The total number of pine and Douglas-fir trees cut (and thus, tops requiring treatment) was 58, or 5.6 per acre.

COST OF CONTROL MEASURES

The total cost of the spraying operation (exclusive of travel) was $273.40, about one-third in materials and two-thirds in application costs (table 1).

How useful our cost experience will prove in other areas is open to question. A lot of variables influence insect-control cost: terrain, accessibility, amount of material requiring treatment, total volume of timber cut, amount of logging debris, and density and type of understory. Some forest managers may prefer to consider the per-acre cost in relation to number of tops per acre. This was the only cost relationship which was consistent for all treated compartments and it closely approximated a straight line with the formula $Y = 0.87 + 0.43X$, with Y representing cost and X the number of tops (fig. 2).

Other managers may prefer to draw on averages compiled for the 3 heavily-cut compartments and for the lightly cut stands (table 2).

None of these cost figures includes travel costs to and from the job. This variable should be added when using these data in estimating costs.

Table 1.--Cost of lindane spraying on pine engraver beetle project, Challenge Experimental Forest, 1959

Item	Cost
	Dollars
Materials and preparation:	
Lindane (3 gallons) and kerosene (240 gallons)	$ 94.00
Mixing spray (10.5 man-hours)[1]	27.30
Sub-total	$121.30
Application of spray:	
Heavily-cut compartments (51 man-hours)	$132.60
Lightly-cut compartments (7.5 man-hours)	19.50
Sub-total	$152.10
Total project cost	$273.40

[1] Wage rate: $2.60 per hour (weighted average rate of spray-crew members).

Table 2.--Average cost of treating slash with lindane for heavily and lightly cut stands by various units of measure, Challenge Experimental Forest, 1959

Item	Heavy cut	Light cut
Area cut, acres	29.00	10.40
Pine volume cut, 1,000 bd. ft.	590.50	[1]90.03
Tops treated, number	501.00	58.00
Total cost, dollars	238.34	35.06
Average cost in dollars per:		
Acre	8.22	3.37
1,000 bd. ft.	0.40	0.39
Treated top	0.48	0.60

[1] Douglas-fir included in lightly-cut stand volumes.

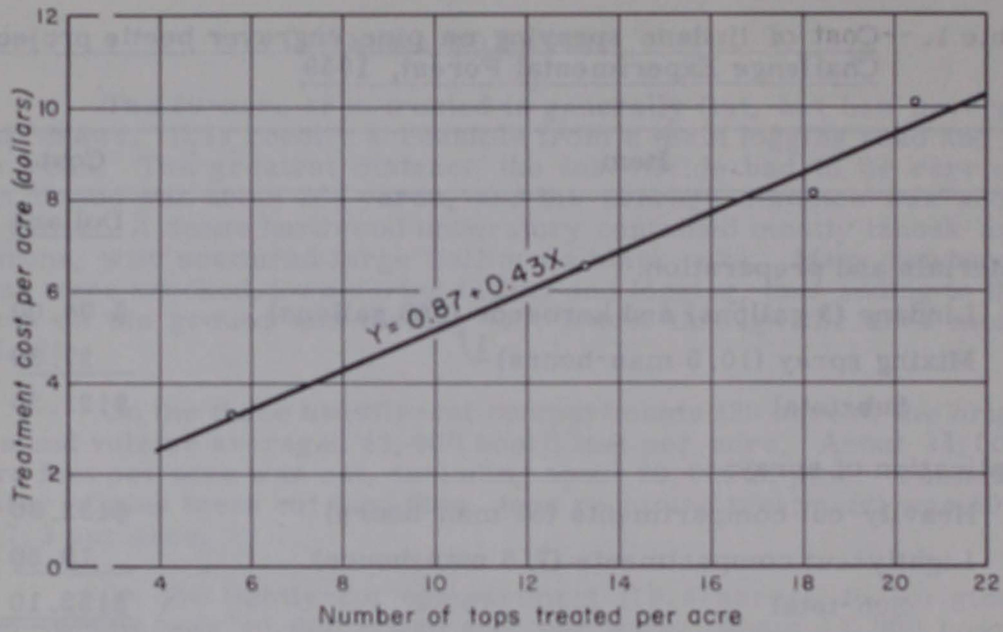

Figure 2. --Per-acre cost of spraying slash with lindane, as related to number of tops sprayed per acre, Challenge Experimental Forest, 1959.

WAS CONTROL ACHIEVED?

Because the trial contained no untreated check areas and no replications, we cannot say positively that the treatment was effective. However, only 1 pole-sized tree in the treated area was killed even though heavy broods were present in the slash. A small group of trees, all under 20 inches in diameter, was killed in a nearby area, probably by beetles from a small amount of untreated road-construction slash. None of the top-killing frequently associated with pine engraver attacks was visible by early winter. In contrast, extensive engraver damage followed other 1959 spring logging on sites at low elevations where slash was not treated. Outbreaks were reported in Amador, El Dorado, Nevada, Placer, Plumas, Shasta, and Yuba counties, among others. Groups of 4 to 60 trees were killed, including trees up to 36 inches in diameter. The tops of even larger trees were damaged.

MINOR PROBLEMS ENCOUNTERED

Two problems cropped up during the operation. We found it difficult to keep backpack spray containers from leaking. The use of a sprayer with a positive leak-proof top is essential for safety and comfort. We also found it difficult to keep track of the areas which had been sprayed. The kerosene evaporates quickly, and the residue of lindane is invisible unless the sun happens to strike the crystals just right. We were reluctant to add coloring for fear of altering the crystalline structure of the lindane residue. This problem has been called to the attention of the entomologists who tested this insecticide. If they can recommend a coloring agent which will not affect the lindane residue, future spraying jobs can be done more efficiently.

CONCLUSIONS

Lindane proved economical and practical to apply. The evidence of its effectiveness is meager but favorable: after spraying, little subsequent damage occurred in the residual stand despite proximity to heavily infested fresh logging slash. This residual-type insecticide may provide a valuable tool for forest managers to use in preventing heavy losses from pine engraver build-ups.

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MISCELLANEOUS PAPER
No. 45
February 1960

PSW FOREST AND RANGE
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A SIMPLE PYROMETER FOR MEASURING SOIL TEMPERATURES DURING WILDLAND FIRES

by

R. L. Fenner, formerly Range Conservationist
and J. R. Bentley, Range Conservationist

INTRODUCTION

Grass, brush, and forest fires subject the upper inches of soil to intense heat for short intervals. This heat causes significant physical. chemical, and biological changes in the soil, litter, and vegetation. A measure of heat in the upper soil helps to explain plant succession and soil condition associated with fire. This may be a difficult measure to obtain. Combustion occurring on the entire burned area influences heat transfer at any particular point through conduction, convection, and radiation. Consequently, temperature data from small fires or from the perimeter of large fires fail to represent conditions at specific points within large burns. Measuring fire temperatures within a large burn is normally a difficult and expensive task.

A simple, inexpensive instrument which will provide such measurements was used successfully in 1952 by the authors to measure soil temperatures associated with recognizable postfire soil surface conditions (Bentley and Fenner, 1958). The pyrometer can be further developed and adapted to different uses to provide better understanding of the heat input variables during burning and the associated effects on soil and vegetation.

KINDS OF SOIL TEMPERATURE RECORDERS

A review of the literature showed that several pyrometric devices have been used to measure soil temperature in the field during fires: thermocouples, resistance thermometers, expansion thermometers, and fusible compounds. Other temperature-measuring instruments such as gas thermometers, optical pyrometers, liquid-filled thermometers, radiation pyrometers, and color thermometers have been found unusable for the particular measurements or have not been tried.

THERMOCOUPLES

Thermocouples, which sense temperature of the surrounding medium by generating an electric current in a bimetallic junction, are buried in the soil with wires carrying the current to a galvanometric recording apparatus outside the area being burned. Temperature versus time records have been obtained from small test fires or from the perimeter of large fires under both grass and brush fuels by Craddock and Sampson (1944), Heyward (1938), Burgy and Scott (1952), and Korstian (1927).

The technique provides valuable information. However, the expensive equipment, time for installation, and the problem of laying wires make it difficult to obtain the large number of readings necessary to sample the variability in brush burns. The discrete nature of the observations makes difficult a continuous reading throughout the soil profile. The size and shape of the thermocouple precludes vertical alignment of temperature sensing units within the profile. The size and shape of the thermocouple precludes vertical alignment of temperature sensing units within the profile, and the measurements obtained are from different profiles, each of which may have been subjected to different surface heat inputs.

Burgy and Scott (1952) exposed multiple thermocouple units connected in parallel in the surface litter and soil, obtaining an average temperature measurement for a given area. Readings of this kind provide valuable data on the average intensity and duration of heat inputs at the surface for different fuel conditions, but they do not reflect environmental variability nor provide a vertical picture of heat penetration.

RESISTANCE THERMOMETERS

Resistance thermometers, either platinum wire or thermistors, have essentially the same advantages and disadvantages as thermocouples. The major problem is the complex electrical circuits necessary for their operation.

EXPANSION THERMOMETERS

Soil temperatures during laboratory fires are often determined by inserting several mercury thermometers into the soil at different depths. Burgy and Scott (1952), Sweeny (1954), and Stone and Juhren (1951) have used this technique. The system is satisfactory for soil temperatures below 400° F., which are commonly encountered in the laboratory where radiation and convection losses are high and heat conducted into the soil is consequently low. Expansion thermometers, however, cannot be read during a fire under field conditions.

Maximum thermometers, used by Korstian (1927), and others, are buried in the soil before the fire and excavated later to record the maximum temperature reached at a specific depth. Many thermometers are required, and the risk of breakage by handling and overheating is high. Vertical stratification of the readings across contact surfaces of litter and mulch or mulch and mineral soil is difficult.

Differential expansion thermometers, which utilize a bimetallic strip, read to high temperatures. This type has been used by Sweeny (1954), but it requires direct reading and is therefore suitable only for laboratory type fires.

FUSION PYROMETERS

The melting point of specific chemical compounds is used in fusion pyrometers to indicate maximum temperature reached in the surrounding medium. Melting points of pure compounds are very precise, and compounds are available commercially in the range of 113° F, to 2,000° F.

Pyrometric or Seegar cones used in ceramic firing are not discussed here as they respond to temperature and time periods which are normally higher than those in which we are interested. Fusible plugs have been used to measure temperatures in oil wells.

Beadle (1940), in Australia, buried small pill boxes at depths of 1 to 15 inches in the soil beneath wildland fires. Each box contained glass vials of chemicals which melted at different temperatures, giving him the maximum temperature reached at each depth. The disadvantage of this method is that it provides discrete readings of temperature at discrete depth intervals. Its advantage lies in simplicity of operation, low cost, and adaptability to field conditions.

Another method of using fusible compounds is reported here. It consisted of inserting continuous strips of different fusible compounds vertically into the soil. Melting temperatures of the compounds varied from 150° F.--the killing temperature for protoplasm--up to 1,200° F.--flame temperature. After the fire the depth to which a strip melted indicated the deepest penetration of the particular temperature front associated with the melting point of that chemical. This technique is particularly adaptable to the problem of measuring temperature penetration in the surface layer of the soil across litter-mineral soil interfaces. The technique is not a substitute for other methods. But it provides a simple, low-cost, automatic heat-sensing instrument to supplement other devices used in investigation of wildland fires.

DESIGN AND CONSTRUCTION

The pyrometer (fig. 1) is a thin plate made from ordinary sheet mica and coated with strips of fusible compound. Cleavage planes permit splitting the mica into sheets about 0.002 inch thick. The plates used in the first instrument were 2 1/2-inches wide by 2 3/4-inches tall. The width and depth (height) of the plate will depend on the number of temperature strips required and the depth to which readings are to be taken.

The fusible compounds are pure organic chemicals dissolved in a volatile solvent. While in a liquid state the solution is painted or printed on the mica plate in parallel strips about 1/10-inch wide. When the solvent evaporates, strips of crystalline solid remain. The melting points of the chemicals used[1] in the original instrument, in ° F., were: 150, 200, 250, 350, 450, 550, 650, 750, 950, 1,150.

Several methods of applying fusible chemicals to the mica have been tried, each with success after the technique was mastered. The chemical is dissolved in prepared thinner or a solvent such as Toluene. The solution has been applied with an eyedropper, with a brush, or by printing it on the mica with the edge of a high-rag-content card of the proper size. Each compound reacts differently and considerable care is required to obtain and maintain the proper consistency for each.

The fusible strip with the highest melting temperature is placed along the left edge of the mica sheet and those with progressively lower melting temperatures towards the right.

The plate is then faced with a sheet of asbestos paper 1/32-inch thick. The smooth side of the asbestos is placed facing the dry chemicals on the mica plate, and the two are then fastened together at the base with wire staples. The asbestos serves to protect the chemicals, support the fragile mica, and absorb the chemicals when they melt. The assembled pryometer is ready for field use.

Mica has approximately the same heat conducting property as dry soil. The horizontal transfer distance of heat from the surrounding medium is short through the thin mica plate. The insulating property of the mica sheet prevents excessive vertical heat transfer, which occurs if the plate is glass or metal. The thermal conductivity of asbestos is low, so it does not affect the temperature penetration being recorded on the mica face. The cellulose filler in the asbestos paper chars to

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[1] Tempilaq°--a product of Tempil Corporation.

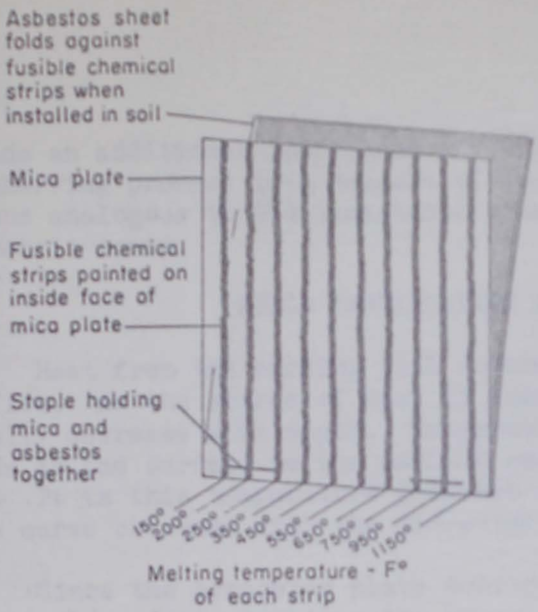
Asbestos sheet folds against fusible chemical strips when installed in soil
Mica plate
Fusible chemical strips painted on inside face of mica plate
Staple holding mica and asbestos together
150°
200°
250°
350°
450°
550°
650°
750°
950°
1150°
Melting temperature - F° of each strip

Figure 1.--Fusion pyrometer, showing how strips of fusible chemical are located on mica plate.

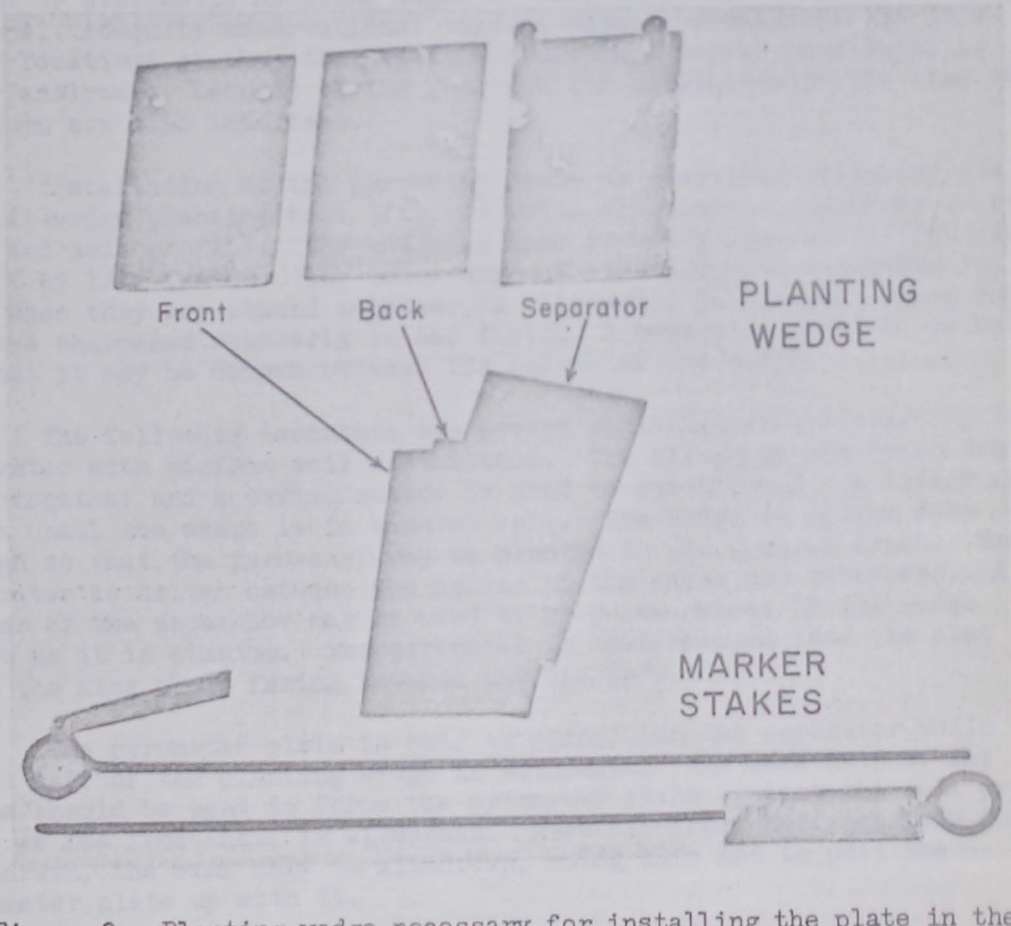
Front
Back
Separator
PLANTING WEDGE
MARKER STAKES

Figure 2.--Planting wedge necessary for installing the plate in the field, and marker stakes used to locate the plate after the fire.

provide an additional indication of temperature duration and intensity. The charring process is a measure of "heat-work" and the degree of charring is thus analogous to the time-temperature indicating properties of pyrometric cones.

FIELD INSTALLATION AND RECOVERY

Heat from the burning fuel enters the surface of the soil during the fire. As the source of heat is from above, the temperature will normally decrease with depth. Temperatures range from 1,200° F. in the flames at the surface to the ambient soil temperature somewhere in the soil. It is this temperature gradient which is shown by the temperature-depth curve obtained with the pyrometer.

Since the pyrometer plate provides temperature measurements at a particular point, locating the pyrometer stations to sample field conditions is important. A system of stratified sampling was used. Random or systematic sampling might be more useful under certain conditions. Adequate observational records should be taken at the pyrometer locations so that the pre-fire conditions may be considered in later analyses. Records of the fuel and air conditions at the time of the burn are also important.

Installation of the pyrometer plate is simplified with the aid of a split-wedge planting tool (fig. 2) which minimizes disturbance of the fuel and soil profile. The wedge is made from two pieces of sheet iron, 3 by 5 by 1/16 inches. The lower edge of each piece is sharpened so that when they are placed together, a thin wedge is formed. These edges must be sharpened regularly in the field. A separator sheet is sharpened so that it may be driven between the halves of the wedge.

The following technique has proved satisfactory for planting the pyrometer with minimum soil disturbance. The halves of the wedge are held together and a sawing action is used to cut through the litter and mulch until the wedge is in mineral soil. The wedge is driven deep enough so that the pyrometer may be planted to the desired depth. The separator is driven between the halves of the wedge and withdrawn. A corner of the separator may be used to hold the halves of the wedge apart as it is planted. The pyrometer is then dropped into the slot with the mica plate facing towards the operator.

The pyrometer plate is held in place with the separator while the front half of the planting wedge is withdrawn. The back half of the wedge should be used to force the pyrometer plate against the soil profile as the front half is withdrawn. When the front half has been fully withdrawn, the back half is withdrawn, using care not to pull the pyrometer plate up with it.

The wedge is then driven into the soil 2 or 3 inches behind the pyrometer to force the slot closed tightly around the pyrometer. If the top of the litter layer does not correspond with the top of the pyrometer, it should be indicated by a mark on the pyrometer. Metal marking stakes should be placed on each side of the pyrometer plate and in line with it to facilitate location after the fire.

After the burn, the pyrometer is relocated and excavated from the soil. Excavation is carried out on the mica side of the pyrometer plate. A spatula and small brush are useful in this operation. As successive layers of ash, litter, and soil are removed, the lines of demarcation between the layers are recorded in ink on the mica face of the pyrometer. Recognizable strata will vary with soil types and fuel conditions. The mineral soil level is the most constant reference level to use. The dividing line between humus and mineral soil may range from sharp to indefinite, depending on the soil type and fire intensity.

After the front of the mica plate is fully excavated, the pyrometer is withdrawn from the seedbed, exposing the asbestos side. This side indicates the intensity of charring. The depth of char is revealed even when decomposed organic matter, or the complete absence of organic matter in the soil, obscures the charring effect. The shading from light to dark char and the area covered by each are difficult to describe. but one who uses the instrument soon finds it a most useful indicator of temperature and duration. A similar technique is described in most cookbooks, by which oven temperature can be estimated rather accurately without a thermometer from the degree of charring of flour or paper. Additional investigations are needed to make full use of the char indicator on the asbestos sheet.

Information from the temperature curve on the mica side and the intensity of char on the asbestos side are immediately available in the field as an aid in the recording of post-fire conditions. Extreme non-conformity of either may lead to the discovery of some extraordinary conditions which would not be noticed otherwise.

KINDS OF RECORDS

In the office the mica plate and the asbestos sheet are separated for detailed analysis. The plate is best examined against a black background under reflected light. A 10X hand lense is useful in recognizing melt points. A short inked line may be placed on the mica at the melt point of each strip to facilitate measuring, and for checking at a later date.

The mica plate then clearly shows the shape of the temperature-depth curve. Depth of each specific temperature front below or above a reference line can be measured. Mineral soil surface is the best reference line. Other measurements also may be used to correlate different factors with intensity of the fire.

Records from the various pyrometer stations can be combined and plotted to provide average or characteristic curves for particular conditions. We found that pre-fire fuel stratification resulted in a characteristic curve for each class.

Each mica plate is a direct, permanent record of the thermal input at a particular location. The input from radiation, convection, and conduction heated the surface soil and the energy was transferred downward, largely by conduction. As surface input diminished the various temperature fronts continued to penetrate into the soil until the energy was dissipated. Depth of each iso-thermal line is shown by the melting depth of a specific chemical compound.

SUMMARY

A simple, inexpensive pyrometer has been developed for use in gathering temperature data from the upper soil during wildland fires. The pyrometer employs fusible compounds painted or printed on a thin mica plate backed with asbestos. The plate is buried vertically in the soil with the aid of a special split-wedge planting tool. The pyrometer automatically records the depth of penetration of selected temperature fronts into the soil during the fire. Temperature fronts from 150° F. to 1,150° F. have been recorded. The depth-temperature curve can be observed in the field at the time the pyrometer is removed.

The pyrometer can be filed as a permanent record and is a source of basic data from which several types of heat measurements may be taken. The records can supplement those taken by thermocouples or thermometers.

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PACIFIC SOUTHWEST
FOREST AND RANGE
EXPERIMENT STATION
BERKELEY - CALIFORNIA

MISCELLANEOUS PAPER

No. 46 March 1960

A RECORD DROUGHT IN THE FOOTHILLS

By Don A. Duncan and Jack N. Reppert
Range Conservationists
Division of Range Management and Wildlife Habitat Research

Like much of California's foothill area, the San Joaquin Experimental Range, near O'Neals, Madera County, received abnormally low rainfall during the 1958-59 season. Also, even though the 1959-60 season began with a heavy rain on September 19, 1959, a dry spell the next 96 days extended the effects of drought. Herbage production dropped to a new low. Yet for several reasons cattle made substantial weight gains on the range with relatively light feeding of supplements.

The San Joaquin Experimental Range, including about 4,600 acres at an elevation of 700-1,700 feet in the western Sierra Nevada foothills, is representative of the annual plant type found in the granite-soil area of the foothills, and to a lesser extent is comparable to several million acres of annual-plant rangeland in California. Some of the problems encountered in conducting rangeland research on the Range are the same ones facing many foothill ranchers.

These problems originate from basic soil, climatic, and vegetative factors such as a shallow soil with low water-holding capacity, definite wet and dry seasons, and annual-type plants that respond readily to fluctuations in moisture and temperature (resulting in distinct forage or feed "seasons"). The widely fluctuating forage supply available from year to year and how to best utilize this resource within the vegetative seasons are ever-present problems. The rancher operating entirely on annual-type foothill range, seeks the most efficient possible use of available forage so he can reduce to a minimum the amount of expensive supplements needed to keep his herd productive. Even the foothill rancher who uses other ranges (mountain range, irrigated pasture, stubble, etc.) for parts of the year must use the annual-type forage on the home ranch efficiently to round out and streamline his cattle operation. Generally speaking the average years or good years do not pose a serious problem; the bad years or drought years on the foothill ranch bring on the headaches--and big feed bills.

Rainfall

Detailed weather records have been kept at the San Joaquin Experimental Range since 1934. The 10.12 inch rainfall for the 1958-1959 season, barely half the 25-year average of 19.53 inches, was the lowest ever recorded (fig. 1). Probably more important, rainfall distribution was very unfavorable; only January and February produced rains spaced favorably for plant growth. From February 23 to April 26, when plants were capable of making maximum growth, only 0.04 inches of rain were recorded. After this dry period, the rain that fell late in April was "too little and too late". It was of little value to the total herbage production because most of the vegetation had already matured or dried.

As far as rainfall records go, the drought of 1958-59 ended when the 1959-60 season began with a record-shattering 3.70 inches of rain on September 19, 1959. This soaking rain brought about extensive germination, and plant growth was good for several weeks. But then much of the new vegetation stopped growth and died during the 96 rainless days following the first storm. No rainfall was recorded in either October or November (another "record") and only 0.36 inches of rain fell in late December. For the last quarter of 1959, rainfall was only 6 percent of normal.

Herbage Production

The effect of the 1958-59 drought year on plant growth was a new low in herbage production:

Year:	Herbage production (Pounds per acre, air-dry)
Average (25 years)	1,650
1951 - highest	2,600
1949 - previous low	1,100
1959 - new low	690

Less than half of an average forage crop was produced in 1959, by far the lowest ever. If the area had been more heavily grazed the previous year, production would surely have been even lower. Relatively light grazing in 1957-58 had left an appreciable amount of litter, or old growth, on the ground. This litter, by providing shelter for the young plants and by reducing evaporation, undoubtedly made possible some "extra" growth during the unfavorable 1958-59 season.

As every foothill rancher well knows, total forage production is not the whole story; the length of time sufficient green feed is available is also important. It is during this season that the largest numbers

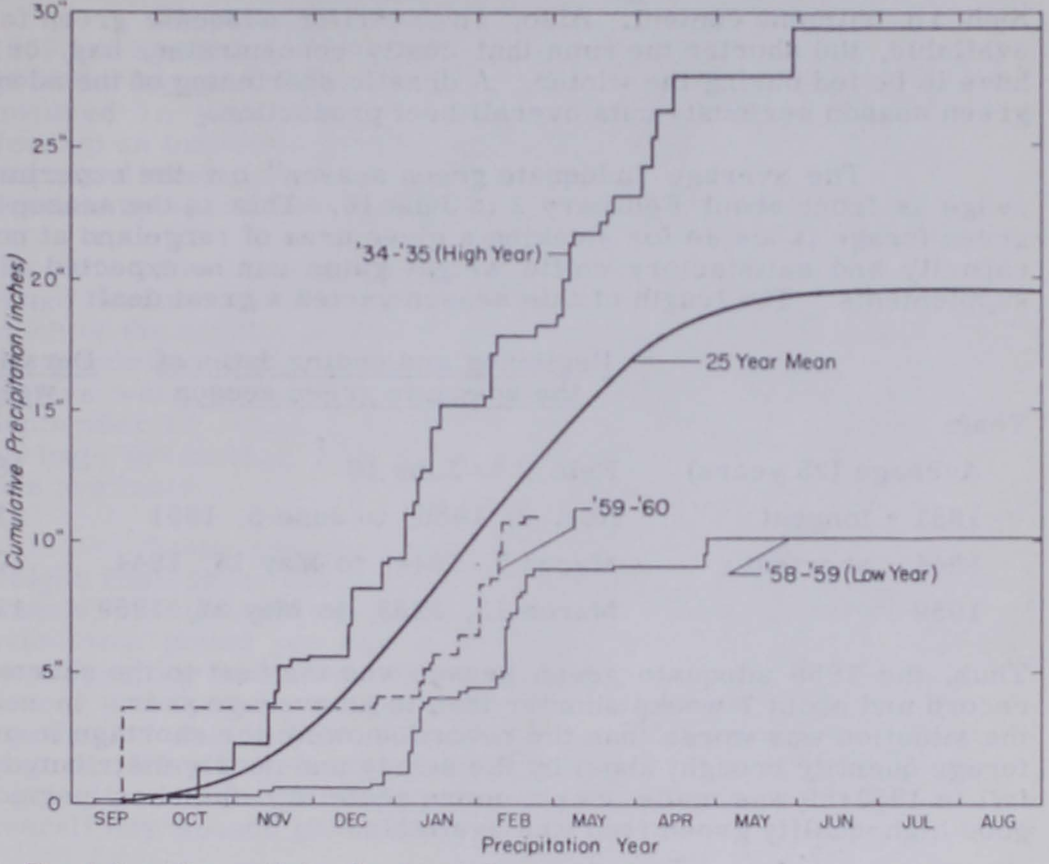

Figure I. Cumulative precipitation, San Joaquin Experimental Range.

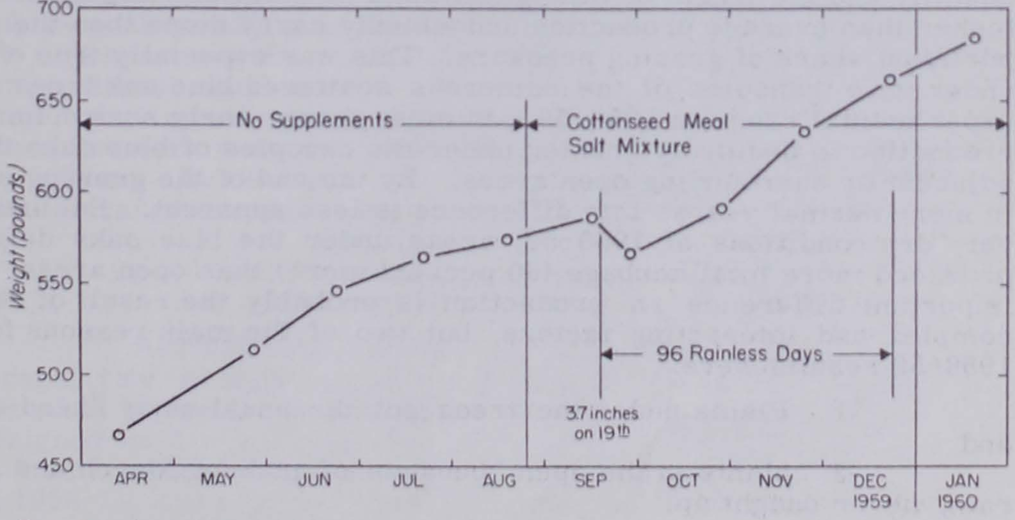

Figure 2. Heifer weights, San Joaquin Experimental Range.

of cattle are on the foothill ranges, and maximum beef gains are usually made when forage is abundant, attractive to livestock, and high in nutrient content. Also, the earlier adequate green feed is available, the shorter the time that costly concentrates, hay, or both have to be fed during the winter. A drastic shortening of the adequate green season seriously cuts overall beef production.

The average "adequate green season" on the experimental range is from about February 2 to June 10. This is the season when green forage is ample for stocking a given area of rangeland at normal capacity and satisfactory cattle weight gains can be expected without supplements. The length of this season varies a great deal:

Year:	Beginning and ending dates of the adequate green season	Duration in weeks
Average (25 years)	Feb. 2 to June 10	18
1951 - longest	Nov. 2, 1950, to June 5, 1951	31
1944 - shortest	March 7, 1944, to May 16, 1944	10
1959	March 13, 1959, to May 27, 1959	11

Thus, the 1959 adequate green season was the next to the shortest on record and about 7 weeks shorter than in an average year. In reality, the situation was worse than the record showed; the shortage in overall forage quantity brought about by the scanty and poorly distributed rainfall in 1958-59 was made even more acute by the short period that good high-quality green feed was available.

In such periods of very short herbage production, both in quantity and the length of time green feed is available, small areas of higher than average production undoubtedly carry more than their proportional share of grazing pressure. This was especially true of areas under the canopies of the numerous scattered blue oak trees on the experimental range in 1958-59. In most years, early season herbage production is decidedly greater under the canopies of blue oaks than in adjacent or surrounding open areas. By the end of the growing season in more normal years, this difference is less apparent. But under the very dry conditions of 1958-59, areas under the blue oaks definitely produced more total herbage (60 percent more) than open areas. This important difference in production is probably the result of several complex and interacting factors, but two of the main reasons for the 1958-59 results were:

1. Plants under the trees got the usual early "head start," and

2. plants in the open, because of lack of March and April rain, never caught up.

Cattle Performance

The all-time low rainfall and herbage production in 1958-1959 are a matter of record. How did the cattle fare? In April 1959, 99 uniformly good Hereford heifers were received. These heifers are involved in yearlong and varied seasonal grazing trials designed to develop an improved grazing system for annual-type rangeland. High sustained beef production without deterioration of the range resource depends upon efficient, practical grazing management.

The cattle were first put out on the range about a month after range readiness (the beginning of the adequate green season), but already much of the vegetation was mature and dry. Soon afterward the bulk of the important forage plants dried out. So for practical purposes the heifers were primarily on dry native vegetation from mid-April until September 19, when 3.70 inches of rain fell. Despite all-time low herbage production, the heifers did very well on the dry forage that was available.

In the 156 days from April 13 to September 16, the average weight rose from 466.5 to 585.8 pounds (fig. 2). This gain of 119.3 pounds, 0.76 pounds per heifer per day, varied seasonally from slightly over one pound per day in May and June to a low of about one-third pound per day in August. Adequate water and salt were available at all times, and the only supplement used during the 156 days was a small amount of 2:1 and 3:1 cottonseed meal-salt mixture put out in late August. Very little of the meal-salt mixture was consumed (less than a pound per heifer per day), so the supplement had little effect on the overall dry-season gain.

Thus, even though the 1958-59 season produced the lowest herbage yields on record, the forage that was available was evidently of high quality. This is borne out by the fact that cattle gains during the dry season were higher than usually recorded in "good" forage years without supplements. Many foothill ranch operations utilize the home range mostly during the adequate green season and the inadequate green (winter) season. Often, cattle are on other ranges during the dry season. In 1959 yearlong foothill ranchers whose animals grazed similar range during the dry season found the dry feed to be "strong".

Other Effects

Although the cattle gained well on the scanty but "strong" dry forage, the drought severely hindered the start of new long-time research studies. The range units in the new study were necessarily designed with a grazing capacity based on normal herbage production in mind. Since the units produced less than half an average forage crop in 1958-59, the supply became short earlier than would usually be the case. Ordinarily an acre of this foothill range will carry a yearling heifer for 18 days. This year a safe capacity was about one-third as much--actually less than 7 heifer days per acre. In other words, to maintain the cattle and range in good condition it was necessary by late September to either feed hay or move the animals to units with more available dry forage. The latter practice was followed and a cottonseed meal-salt mixture supplement was used.

Furthermore, stock water became an increasingly serious problem as the drought continued. Many springs dried up early in the year. Some of the better springs had never been known to dry up in past years, and others which usually dried up in the fall were bone-dry by mid-summer. Water had to be hauled to several of the study units over an unusually long period. The heavy rain in September 1959 did very little to ease the water-hauling job. It was still necessary to haul water to some experimental units in January 1960.

During the inadequate green season, or after the heavy rain on September 19 leached out the dry vegetation and started germination of the 1959-60 forage crop, the 99 heifers did well on a cottonseed meal-salt mixture and the available old growth. A weight loss occurred in late September when the animals stopped eating the old growth and began seeking the tiny new green plants (fig. 2). However, when the heifers were moved to a range unit with more old growth available, they went back to grazing the old growth and began taking more of the available cottonseed meal-salt mixture. From September 29 through January 20, a gain of slightly over a pound per heifer per day was made without feeding hay.

The light use of the entire experimental range in 1957-58, a past history of moderate use resulting in good species composition on most of the range, and the relatively light stocking rates in 1958-59 no doubt all had a part in making possible such substantial and economical gains during a very unfavorable drought period.

Summary

In summary, the 1958-59 season produced the lowest rainfall and lowest herbage production ever recorded at the San Joaquin Experimental Range. Although the supply was short, the dry forage utilized by the experimental herd was evidently of good quality, as reflected by an average daily gain of more than three-fourths pound per yearling heifer during the 156 days on dry forage with very little green herbage and range supplements. From late September 1959 to January 1960, the heifers gained slightly more than a pound per head per day on primarily old growth herbage and a cottonseed meal-salt supplement. The extremely dry last quarter of 1959 caused death of a large number of newly germinated plants, and only time will tell the ultimate effect of this adverse period on the coming 1959-60 forage crop.

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PACIFIC SOUTHWEST
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Berkeley - California

MISCELLANEOUS
PAPER No. 47
MARCH 1960

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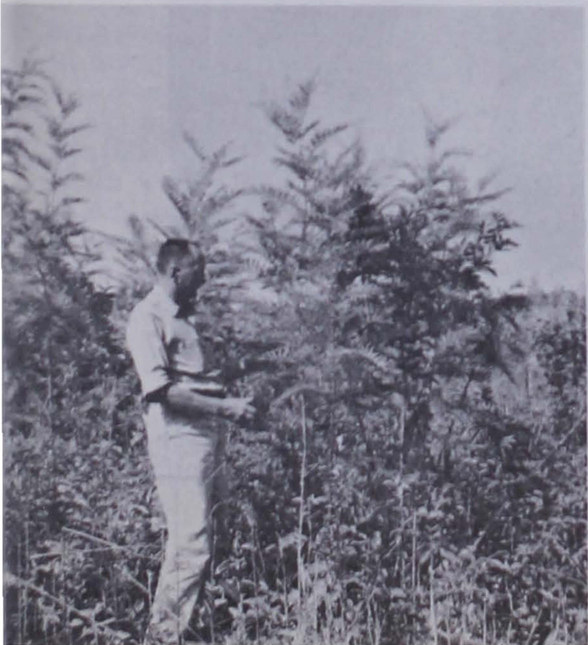
Silk-oak in Hawaii...
pest or potential timber?

by Robert E. Nelson

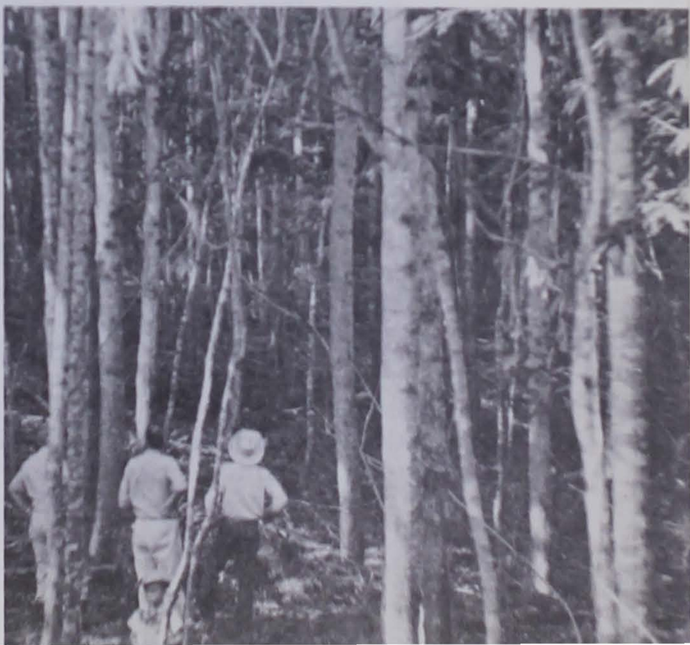
BRUSH. RANGE PEST. NOXIOUS WEED. These are terms ranchers use to describe plants they consider undesirable on their grazing land. In Hawaii, cattle ranchers call the silk-oak tree (Grevillea robusta) by these names and have gone to much expense to eradicate it. But foresters and lumber producers look at this tree in a different light. They see it as a fine forest tree which makes excellent lumber. In fact, they think silk-oak is one of the best timber trees in Hawaii. Watershed managers also consider it an excellent tree for soil stabilization and have planted it in many parts of the Islands.

These contrary viewpoints pose a real problem for land managers. Both meat and wood are much needed commodities in Hawaii. The Islands use more than 100 million board feet of lumber each year, but practically all is imported even though several hundred thousand acres of land are well suited for growing timber. Growing silk-oak as a local source of timber looks like a good opportunity.

Silk-oak is brush to the rancher who bulldozed this area in 1957; he will continue pasture improvement by using herbicides on the 2-year-old silk-oaks and other "weeds".



Across the road, silk-oak is timber to foresters and lumbermen who inspect this 25- to 30-year old natural stand of pole trees and small sawtimber trees which show a high growth potential.



The Opportunity in Planted Forests

The native forests of Hawaii have few timber species of economic importance. Only two, Ohia (Metrosideros polymorpha) and Koa (Acacia koa), occur in sufficient volume to interest timber operators. Koa wood is highly valued for furniture, panelling, and craft products. But the Koa forests are not extensive and few of the trees are good enough for lumber. Ohia, although abundant, has found limited use because the wood is difficult to mill and season and is not suitable for many purposes. The forestry potential of these two species is still in question.

However, many exotic tree species are well adapted to Hawaiian soil and climate. Trials of introduced species began more than 75 years ago. The Division of Forestry in the Department of Agriculture and Conservation and other agencies, as well as private organizations and individuals, have introduced many hundreds of tree species for fuelwood, poles and posts, watershed protection, shade and ornamental uses, and more recently for sawtimber. Only a few have turned out to be promising enough to support a commercial lumber enterprise. Silk-oak is one of these and is adapted to drier sites than most of the others.

Growth rate and form of silk-oak offer an excellent opportunity for timber income. This is a 30-year-old naturalized stand of small sawtimber and pole trees in north Kona.

Young forests of naturally seeded silk-oak: an open stand in the Kau District, and a dense stand in the Kona District, of the Big Island.

Silk-oak Does Well in Hawaii

Introduced from Australia, silk-oak has been planted in many areas on the different islands--on deep soils and shallow, in areas of high and low rainfall and at different elevations. Growth has been good in many locations and exceptional in some.

The light, winged seeds of silk-oak are readily disseminated by the wind, and the species can spread naturally for a long distance from a nucleus of planted trees. Naturalization occurs most rapidly at elevations between 1,000 and 3,000 feet, under a rainfall of 35 to 60 inches, where the soil is deep and well-drained. However, silk-oak also grows and spreads naturally on shallow, rocky soils where rainfall is less than 30 inches.

For timber production, the growth rate and form of silk-oak are excellent. Even open-grown trees tend to grow a straight central stem with few large lateral branches. In dense stands, the trees prune themselves well and develop long clear boles.

A Versatile Wood for Lumber and Veneer

In Australia, silk-oak wood is held in high esteem. It is a beautiful and fine cabinet wood, easy to handle and work: it makes excellent plywood; and it is strong enough for general construction. Some of it is even exported to the United States mainland for furniture manufacture.

Hawaiian Fern-Wood, Ltd. of Hilo has manufactured lumber from a large number of trees grown in Hawaii. Hawaiian silk-oak also is easy to work with and has proved to be very useful for many purposes including panelling, furniture, cabinet work, boxes, and pallets.

Wall panelling for offices and homes in Hilo was milled from these logs at Hawaii Fern-Wood, Ltd. Lower grades of lumber were used for pallets and crates.

Some Problems Unsolved

Although silk-oak is a promising tree for Hawaii, it is not free of problems. Die-back of young tree tops has been observed in some areas. This seriously impairs growth, and affected trees become bushy or limby. The cause has not been determined. Die-back appears to be associated with extended drought, but there may be other causes such as weed-control spray spread by airplanes.

Abundant seed production may be a problem on rangeland. Its ability to spread vigorously poses a threat to some grazing lands; however, many thousands of acres of land in Hawaii have soil and climate well suited for silk-oak but poorly suited for grazing.

To Sum Up

Many acres already are stocked with stands of silk-oak, both planted and naturalized. Some might better be cleared for grazing. Others can produce 25 thousand board feet of silk-oak sawtimber per acre in 35 to 40 years--a return of $30 per acre per year at current stumpage prices. In addition, many acres of idle land, if planted, could grow silk-oak just as rapidly. It is possible, too, that with proper management, silk-oak timber production and grazing would be compatible land uses.

Land owners and managers need facts to help them decide whether silk-oak is a pest to be eradicated or a profitable timber crop to be cultivated. Research will eventually provide such facts, but in the meantime it is important not to overlook the information already available from test plantings and practical experience. These show that silk-oak on the right site can become a potential resource of great value.

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Wood Quality Studies to guide Hawaiian Forest Industries

H. H. Smith

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PACIFIC SOUTHWEST
FOREST AND RANGE
EXPERIMENT STATION
Berkeley - California
in cooperation with
EPARTMENT OF AGRICULTURE AND CONSERVATION
STATE OF HAWAII

FOREWORD

For many years before Statehood, the Bishop Estate and later the Territorial Board of Commissioners of Agriculture and Forestry of Hawaii conducted a cooperative program of timber testing at the U. S. Forest Service Forest Products Laboratory at Madison, Wisconsin.

In 1959, it became apparent that the time had come to re-examine this program and set a course for future wood quality studies. The Board asked the Pacific Southwest Forest and Range Experiment Station to take on the job, and the Legislature provided most of the necessary financing.

This report is the outcome. It represents one of a series of forest research projects which were started under the old Board and which are now being continued cooperatively by the new Department of Agriculture and Conservation and the Forest Service.

WOOD QUALITY STUDIES
TO GUIDE HAWAIIAN FOREST INDUSTRIES

By H. H. Smith, Technologist
Division of Forest Products Utilization Research

Miscellaneous Paper No. 48

April 1960

U. S. DEPARTMENT OF AGRICULTURE--FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE
EXPERIMENT STATION

In Cooperation With

DEPARTMENT OF AGRICULTURE AND CONSERVATION
STATE OF HAWAII

Thirty-two years old, this eucalyptus plantation contains an estimated 40,000 board feet of harvestable timber per acre.

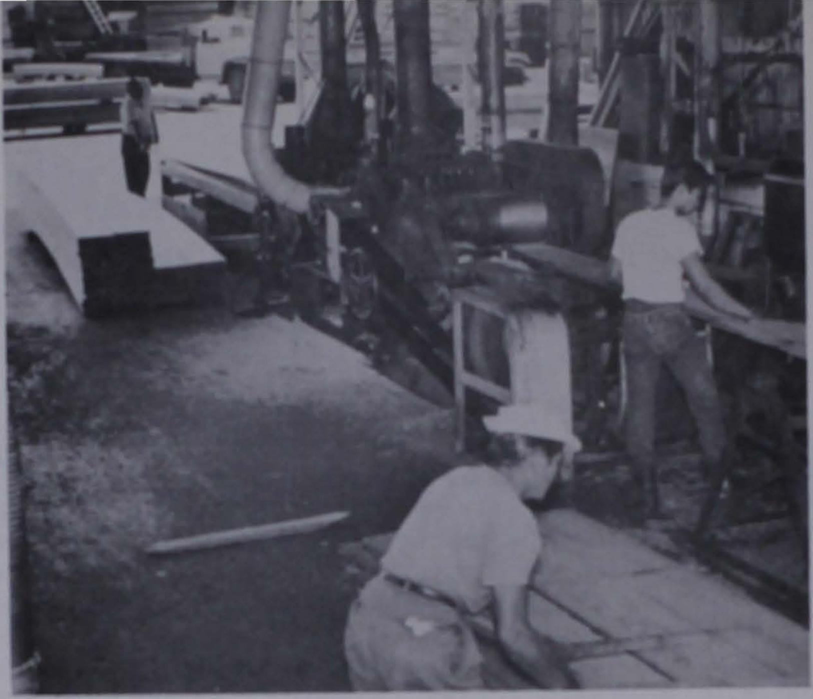
WOOD QUALITY STUDIES
TO GUIDE HAWAIIAN FOREST INDUSTRIES

By H. H. Smith

Hawaii's forests offer a chance to strengthen the Islands' economy through expansion of the present small forest products industry. A high potential for timber growing has been demonstrated by several introduced forest tree species. On favorable sites some stands have reached merchantable size in 40 years or less. But relatively little is known about the wood properties which affect manufacture and use of products from Hawaii-grown timber. Do the introduced species have the same qualities as when grown in their natural range? How do the native and introduced species compare with imported timber products that are used and well known in the Islands?

Some answers to these and other questions have come from studies of the mechanical and physical properties of local woods started about 10 years ago. Few species, however, have been studied in any detail. The U. S. Forest Products Laboratory, at Madison, Wisconsin, has investigated the strength and certain related properties of six species, and some veneer cutting and drying characteristics of two of these. Local manufacturers have studied drying behavior of several species which appear suited for lumber. These studies are a logical starting point but not comprehensive enough to provide an adequate background for industrial development. Other properties affect manufacturing and marketing. Research should also take into account the end-use requirements for wood in Hawaii.

Gathering information on these end-use requirements was the aim of a study conducted in Hawaii in 1959. The study included interviews with large users of wood products, lumber dealers, and sawmill operators. It also included inspection of the major forest land areas to see the type of timber available for commercial use in the coming years. The supply of Island-grown timber was not evaluated because a timber resource survey, now being made by the Pacific Southwest Forest and Range Experiment Station and the State Division of Forestry, will develop this information. What this study sought was information that will help select the species of Island-grown timber for further research on wood properties and help recommend the kinds of studies needed to determine their suitability for certain end-uses.



Lumber dealers are able to remanufacture imported timber products to local specifications.

Typical single-wall house construction using redwood siding—Waialae, Honolulu, Hawaii.

HAWAII USES WIDE RANGE OF TIMBER PRODUCTS BUT FEW SPECIES AND GRADES OF LUMBER

Timber products in all the variety known to commerce are consumed in Hawaii: lumber and plywood for construction, manufacturing, and shipping; poles, piling, and other "roundwood" products; paper, paperboard, and other pulp products. This varied market is being supplied almost completely by imports— all the paper and pulp, all roundwood but a small amount of posts, and all but a small fraction of the lumber.

Three timber species—Douglas-fir, redwood, and oak— supply 98 percent of the Islands' lumber requirements. Annual consumption is forecast at 110 million board feet during the next 5 years. Of this amount, 93 million board feet will be used in construction each year, for framing, sheathing, siding, forms, and other purposes. Two-thirds is expected to be Douglas-fir, one-third redwood. Another 10 million board feet of Douglas-fir and redwood will go into flooring and millwork. The remaining 7 million board feet will be hardwood lumber, mostly oak flooring from the mainland and Phillipine lauan.

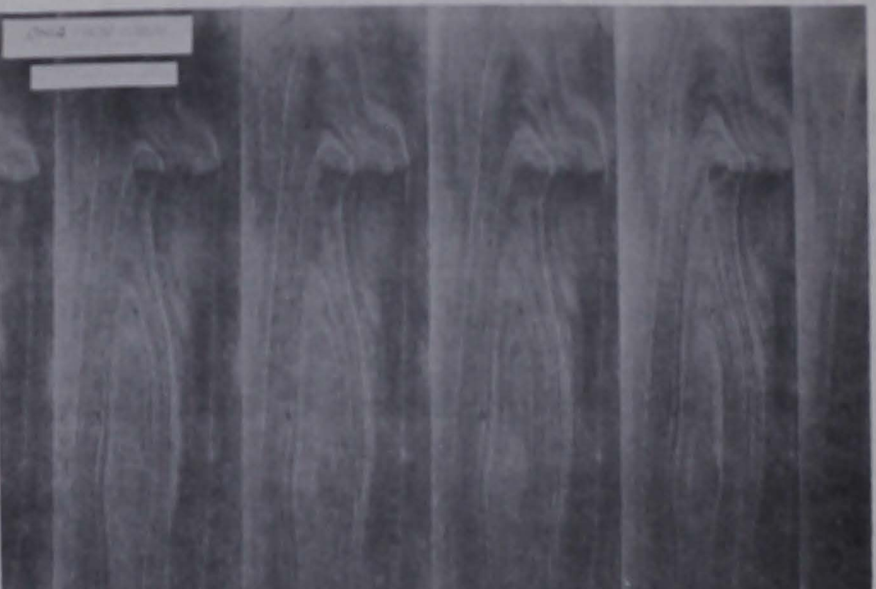
Lumber imports are also restricted to a few grades. Only higher quality material is considered suitable for the Hawaiian market. The size range is narrow too: mostly 4/4 (inch-thick) boards and dimension lumber in Douglas-fir, 4/4 x 6- and 8-inch tongue and groove siding in redwood, and nominal 1-inch flooring in oak.

Why is the selection so limited? One reason is the reliance on off-shore sources, which permits buyers to specify only the grades and sizes they want. Then, too, the lack of local producers means that the wide range of grades and sizes usually produced at local sawmills does not have to be fitted into the lumber economy. And high transportation costs require importing of only the better grades, so remanufacturing costs can be held to a minimum.

CLIMATE AND CONSTRUCTION METHODS PLACE A PREMIUM ON STRENGTH, APPEARANCE, AND DURABILITY OF LUMBER

Use conditions in Hawaii also influence the properties desired in lumber. The mild climate permits single-wall construction of dwellings and light commercial buildings. Construction members, siding, framing, flooring, roof decking, and other components are all load-bearing and exposed. Only the best grades of lumber will provide the strength and appearance this type of construction requires. Even 1-inch softwood and hardwood flooring,

Loading pallets at California plant which manufactures 2,000 units each day. Many will go to Hawaii-bound shipments.



Sample panel of Ohia plywood produced during studies at U. S. Forest Products Laboratory.

which in other states is usually laid over a sub-flooring, is laid directly over floor joists and is load supporting. Such use requires long lengths of relatively clear material.

The mild climate also favors development of decay and insect damage in wood. An unusually important requirement for wood used in Hawaii, therefore, is either high natural resistance or preservative treatment against decay and insects. This requirement explains the local preference for all-heart redwood, which has outstanding natural resistance, and for the heartwood of Douglas-fir, which is moderately resistant.

An assured supply of lumber with these qualities, then, is an important consideration in the choice of material for construction. Douglas-fir and redwood from the West Coast are in a good position to meet this requirement. Many established producers can guarantee the quantities of grades and sizes desired. Furthermore, the large lumber yards in Hawaii have equipment for remanufacturing construction lumber to specification as required.

Relatively small amounts of lumber are used for manufacturing and shipping, but these uses are economically important. The manufacture of craft articles and furniture represents one established outlet for locally-grown woods. Monkey pod and koa are the two most used species. The manufacturers provide a valuable nucleus of operating know-how for an expanded forest utilization program.

Much of the lumber used in shipping and material handling stems from mainland purchases by Hawaiian companies. Virtually all containers, pallets, blocking, bracing, and dunnage originate at West Coast ports. Pallets shuttle back and forth between Hawaii and the mainland. Dunnage that originates on the West Coast is discharged in Hawaii, after a free ride, and often is reused, either as dunnage or as locally fabricated containers and pallets.

FEW SPECIAL REQUIREMENTS EXIST FOR OTHER TIMBER PRODUCTS IN HAWAII

In the main, requirements for other timber products used in Hawaii are about the same as for their use in other states, and wood properties of importance are therefore little different in the Islands.

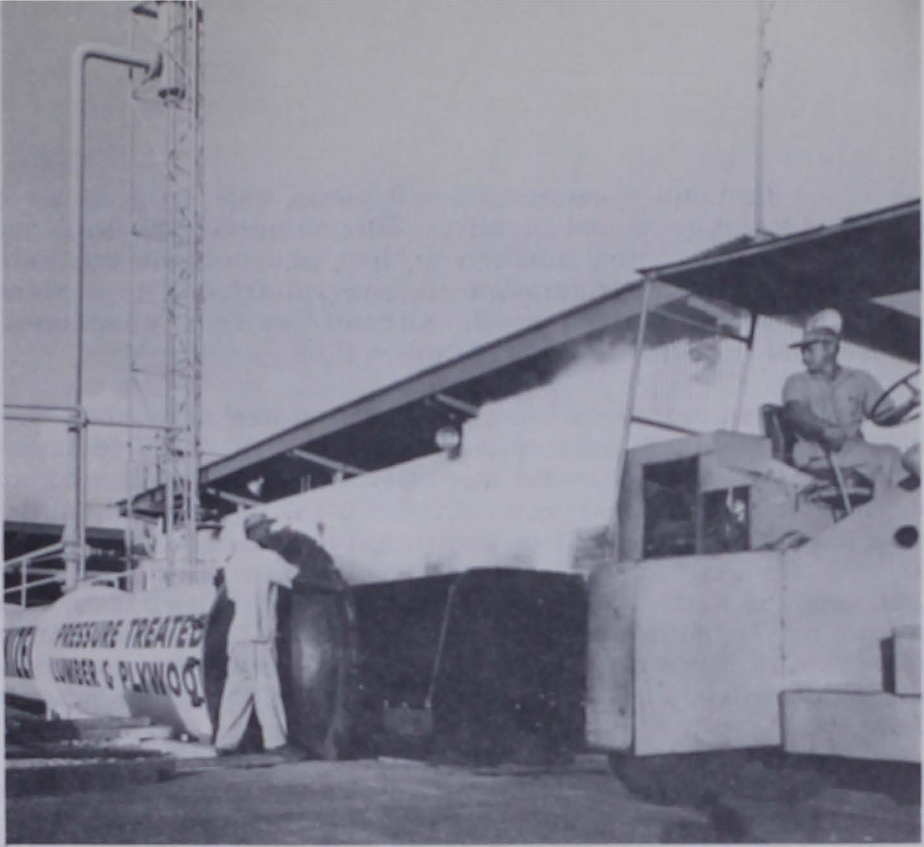
Plywood, here as elsewhere, finds two broad classes of use: a construction type, mostly of softwoods, and a decorative type, predominantly of hardwoods. Island use amounts to about 8 million square feet annually—95 percent softwood, the rest hardwood. Present available island-grown softwood timber is not sufficient to support local production of construction plywood. Some local hardwoods, on the other hand, may prove to be abundant enough and to have suitable properties for high quality decorative plywood. In view of the limited local use (400,000 square feet annually), the bulk of the local output might have to move into offshore markets for furniture, cabinets, and paneling material.

For these uses, appearance is the most important property: the wood must be pleasing to the eye. Other desirable properties are hardness, to resist denting and scratching in service, and relatively low shrinking and swelling with moisture changes, to increase stability of the plywood and to minimize losses during manufacturing. A good wood for veneer and plywood must cut well on the lathe or slicer. The wood must glue and sand well and take a good finish. Manufacturers will also be concerned with properties that affect the handling of veneer logs, bolts, or flitches before they are cut into veneer. Desirable properties include resistance to excessive loss from stain, decay, and insects, and freedom from internal stresses that cause surface-checking and end-splitting during storage and heating.

Although hardwoods appear most promising at present, certain softwoods may find uses once a hardwood plywood operation is established. For example, some may be valuable for specialty items even though the timber supply is limited. Others may be used for core stock to be faced with high grade hardwoods.

Pole requirements in Hawaii, as on the mainland, call for clean, straight, strong, material properly treated to insure long service. The two big consumers are the Hawaiian Electric Company and the Hawaiian Telephone Company. Each uses 800 to 1,000 poles a year, occasionally as many as 2,000. Douglas-fir is the preferred species. Suppliers are West Coast manufacturers who grade, treat, and sell poles to standard specifications. Certified inspectors regrade the poles before shipment to insure compliance to specifications. Consequently a uniformly high grade of poles is used in Hawaii.

The most-used types, by trade classification, are the 40-foot, Class 3 and the 30-foot, Class 5. The power company will use only creosote-treated poles, but the telephone company is interested in trying other types of preservatives on the 25-foot, Class 5 poles used for lead-in lines. Telephone linemen prefer a "clean" pole, one treated with a water or oil-borne preservative rather than creosote.


PRESSURE TREATED
LUMBER & PLYWOOD

Hawaiian wood-treating plant equipped to pressure treat lumber, poles, and posts. (Photo courtesy Honolulu Wood Treating Co., Ltd.)

Hardwood logs from plantations of silk-oak about 65 years old. (Photo courtesy Myron S. Wold)

Current consumption of posts and piling is not known. Most posts are produced locally. The naturally durable species, such as algaroba, are preferred; they are seldom treated. Just now the demand for fence posts is being met from a relatively large but temporary supply of used railroad ties from abandoned lines, and the post market is far from normal.

Requirements for marine piling are extremely rigorous. Only thorough protective measures, such as a full-cell creosote treatment, will enable wood to resist attack by marine borers and provide satisfactory service. Use of local species, then, will require installation of treating facilities of a type not now present in Hawaii. Several species of eucalyptus are now available in the right lengths and size classes for marine piling, if treated, and they would be satisfactory for foundation piling without treatment if used below the water table. Piling may come into more frequent use as buildings are erected on filled land along the waterfront of Honolulu.

Pulpwood or pulp chips have no local market, but one might be developed at the existing or future "soft-board" plants, by using wood to supplement the bagasse which is now the raw material.

INDUSTRIAL EXPANSION HINGES ON DEVELOPMENT OF HARDWOOD MARKETS

If an Hawaiian timber products industry is to be established in the near future, it will have to be based mainly on the hardwood timber which now exists. The Forest Survey will determine just how extensive this resource is. But, even without precise survey estimates, the timber supplies now available are obviously concentrated in the native and introduced hardwood species. Some softwood logs can be harvested from some plantations, but there are not enough softwood sawtimber trees to support an industry.

At first glance this seems like an anomalus situation. Since the import figures show that Hawaii uses softwoods mostly, how can a hardwood-based industry develop and survive?

The answer is that an Hawaiian timber products industry can flourish only through trade with off-shore markets. Any experienced businessman who is thinking about manufacturing Hawaiian woods will realize this. He will want to make his own market investigation and consult the existing public and private sources of information. The difficulty is that no information on potential markets exists. At the Chamber of Commerce timber conference in Honolulu early in 1959 great stress was placed on the need for an economic study of timber industry potentials.

This report is not meant as a substitute for the detailed market data required to attract investors. Rather, it emphasizes the timber quality studies which are needed even before all of the marketing alternatives can be explored.

Nevertheless, it seems likely that the major market for Hawaiian hardwood lumber, veneer, and other products will be found on the mainland. The western states have little hardwood timber; most of it is east of the Mississippi River. Eastern hardwood manufacturers have certain advantages: A wide variety of accepted species, long experience and technical know-how, and established trade channels. On the other hand, the Hawaiian trees can be grown in less time than most eastern trees; high-quality eastern hardwoods are relatively scarce; Hawaiian shipments can be made by water; West Coast markets are growing rapidly; and Hawaii can produce a differentiated product which cannot be produced easily on the mainland.

In addition there may be more local market opportunities than the import figures reveal. For one thing, imported lumber is usually high grade and limited in sizes and thicknesses. Hardwoods cannot be substituted in every use (for example, hardwoods generally weigh more than softwood; they are frequently too heavy for construction, dunnage and containers, but they are preferred for pallets). However, local hardwoods may be able to compete successfully with softwoods when high-grade material is unnecessary but price is an important factor. Because low-grade hardwood lumber seldom can be transported very far, the development of local markets for low grade products could be a particularly crucial factor in the establishment of the industry in the Islands. Then too, the established craft industry will no doubt expand to meet demands of the tourist trade.

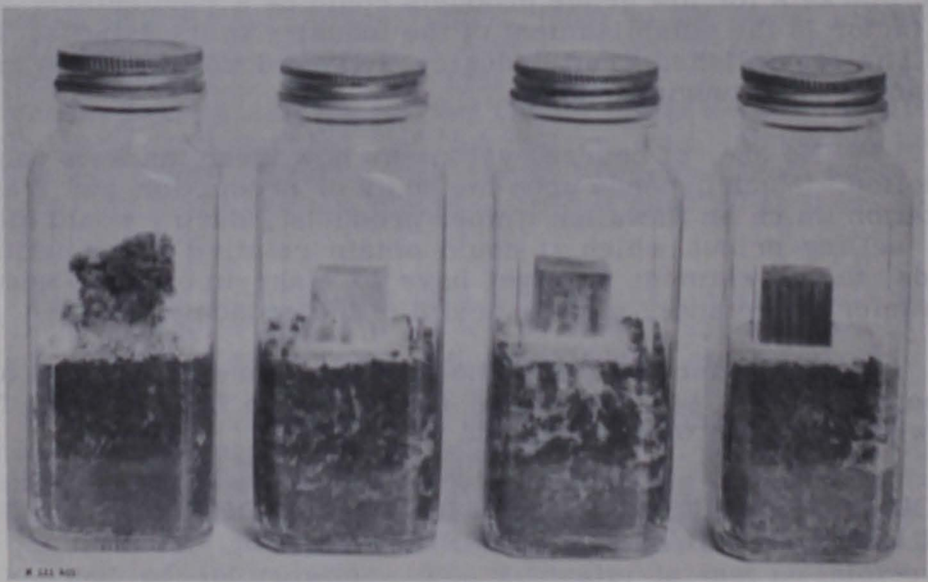
No one, of course, yet knows how these markets can be exploited. Much depends upon the costs of production and transportation which an Hawaiian timber products industry would incur, the selling prices which it could obtain relative to competitive woods, the investment it might have to make in order to secure consumer acceptance, and the health of the economy.

These factors cannot be evaluated here. They will have to be considered separately and soon, but the first job is to find out what Hawaiian woods are good for.

WOOD PROPERTIES RESEARCH RECOMMENDED FOR PROMISING HAWAIIAN TIMBER SPECIES

Both the end-use requirements for timber products in Hawaii and the possibility of export trade suggest that study of Hawaii-grown timber species should go well beyond evaluation of

Manufacture of craftwood products is a well established industry catering especially to tourist trade.



Soil block tests show relative durability of wood samples.

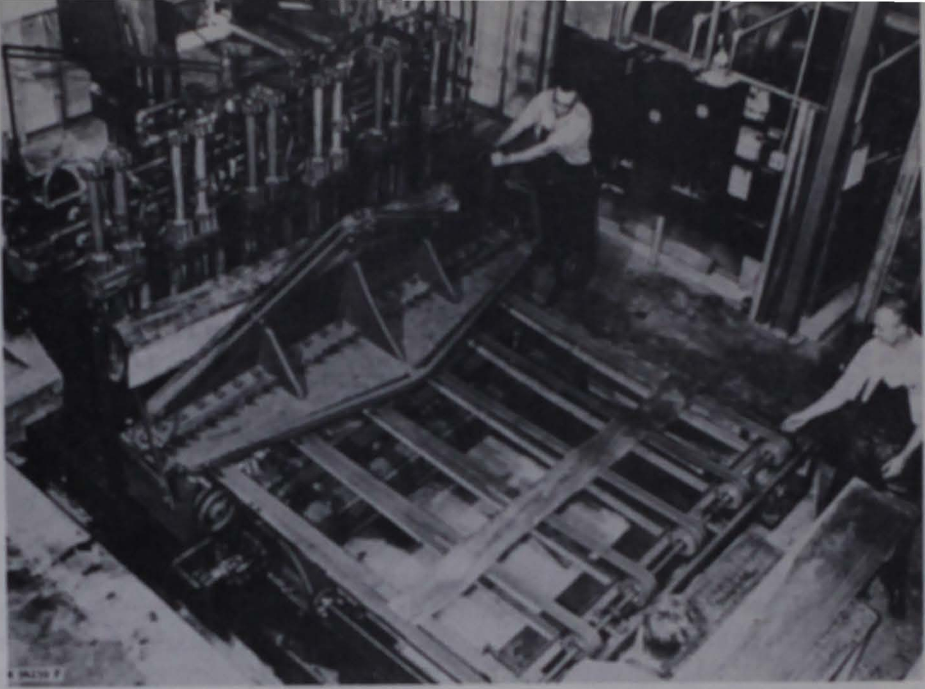
strength properties. Some of the woods will be used where other properties are important: appearance of figure, drying characteristics, and suitability for veneer cutting, machining, and gluing.

Sometimes rather special qualifications may suit a wood for a particular use. A striking example is monkey pod, which is the most important wood in the craft industry because of a very fortunate combination of two outstanding properties: appearance or figure and low shrinkage. These two properties are important for any craftwood--far more important than high strength.

Particularly critical are the many use requirements in Hawaii which call for a high degree of resistance to decay and insects. Few woods have enough natural resistance to permit use without protection. Therefore studies of Hawaiian woods should determine not only their natural resistance to decay and termites, but also whether preservative treatment will protect the wood in high hazard conditions. Modern research techniques have made such tests less time-consuming. The soil block test is a promising new method for studying natural resistance and screening wood preservatives. New exposure techniques standardize and help speed studies of resistance to termites.

Application of results can be speeded by interpreting the results of wood property studies in terms of potential uses for the wood. For example, a good deal is known about the properties of Hawaii-grown shamel ash (Fraxinus uhdei), often called Mexican ash: static bending, hardness and toughness, specific gravity, and shrinkage. These figures have been compared with those of species for which shamel ash might be considered a replacement such as Philippine lauan for paneling and cabinet work or white ash for handles. Thus, we know that shamel ash grown in Hawaii is sufficiently strong for furniture and similar uses, but not for implement handles requiring exceptional strength. Two Hawaii-grown trees--toon, called toona locally, (Toona ciliata var. australis) and cigarbox cedrela, sometimes called Hawaiian cedar, (Cedrela odorata)--have been suggested for use as vertical siding in single-wall construction. A direct comparison with heart redwood as to strength, shrinkage, paintability, and resistance to destructive pests would go a long way toward determining how these two species should be used. Comparisons of this type are a definite aid in introducing new species because the information is easily interpreted by agencies responsible for compliance with codes and specifications.

So far, six Hawaii-grown woods have been studied mostly as to their strength properties (table 1). Some of these species were studied in greater detail than others. The testing



Equipment for veneer slicing studies at U. S. Forest Products Laboratory.

Table 1. --Scope of past studies by U. S. Forest Products Laboratory on Hawaii-grown woods [1]

Properties	Ohia (11 trees)	Eucalyptus multiflora (10 trees)	Toon (5 trees)	Shamel ash (5 trees)	Cigarbox cedrela	Redwood (5 trees)
Strength						
Actual	Green & dry	Green & dry	Limited green & dry	Limited green & dry	Exploratory	Limited green & dry
Comparative	No	No	No	Yes	No	No
Drying	Exploratory	No	No	No	No	Exploratory
Machining	Exploratory	No	No	No	No	No
Veneer cutting and drying	Exploratory	Exploratory	No	No	No	No
Natural durability	No	No	No	No	No	No
Treatability	Exploratory	No	No	Exploratory	No	Exploratory
Pulp & paper	No	No	No	No	No	No

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[1] Common and botanical names are taken from Kelsey, Harlan P. and Dayton, William A., Standardized Plant Names, 2d-Ed., Harrisburg, Pa., 675 pp., 1942, in the interest of providing a recognized source for reference purposes.

program usually included specific gravity, shrinkage, static bending, impact bending, compression, and hardness. For Ohia and E. multiflora, shear, cleavage, and tension perpendicular to the grain were also studied. These species, and others which have not been studied but show much commercial promise, deserve additional attention to determine properties related to their possible end uses.

(1) Metrosideros polymorpha--OHIA

Ohia is the most abundant native species in Hawaii. It is a close-grained, heavy, dense wood of reddish-brown to dark brown color. These properties may make it valuable for special uses. Veneering tests show that Ohia makes a beautiful, dense face veneer suitable for cabinet work, paneling, and furniture, although manufacturing problems may develop because of the shape and size of logs and the abrasive properties of the wood. Ohia veneer would also be excellent for the face ply of plywood flooring. Use as lumber, however, may be limited by the irregular form and small size of most Ohia trees. These factors and its high specific gravity pose some difficulties in sawing and drying lumber. Nevertheless, its strength, color, and hardness may make Ohia suitable for special items of cut stock. It may also be suitable for use as poles, posts, or piling.

Mechanical and strength properties of green Ohia were studied at the Forest Products Laboratory and reported in July 1958. Further research on physical properties would help overcome sawing and drying difficulties and exploit Ohia's desirable properties. The following studies are suggested:

1. Machining
2. Drying
3. Natural resistance to decay and termites
4. Preservative treating

(2) Eucalyptus multiflora (Syn. E. robusta)--BEAKPOD EUCALYPTUS

Also known as browngum and swampmahogany, this species was planted extensively in early reforestation and has grown to good size. (Sydney bluegum eucalyptus (E. saligna) is another of the several eucalyptus planted that has some prospect of utilization). E. multiflora is a heavy, strong wood of red or reddish-brown color. Dense and close-grained, it has been used in Hawaii for flooring even though high shrinkage makes it difficult to handle during logging, milling, and drying. It is best suited for those applications where high strength is important.

Studies of both green and dry wood, published by the Forest Products Laboratory in July 1959, provide good figures for the strength and related properties such as weight and shrinkage. Veneering studies, though only exploratory, show that excellent face-grade veneer of E. multiflora can be produced. These studies all point up the fact that this species has some excellent properties and some that will make it difficult to handle as lumber. More information on other important physical properties may indicate high-value end uses that will greatly facilitate the utilization of this species. Such studies would include:

1. Natural resistance to decay and termites
2. Preservative treating
3. Drying
4. Machining
5. Pulping, to supplement information now available on California-grown E. globulus and Australia-grown eucalyptus species.

(3) Toona ciliata var. australis--TOON

Toon, or toona, is making excellent growth in a few Hawaiian plantations and is one of the more promising introduced species. Wood from trees grown in their native habitat is prized as a cabinet wood and for paneling and interior trim. It is reported to be durable and in many ways equal to the best mahogany. Limited experience with locally grown toon indicates that it should be at least equal to the Philippine lauans for cabinet wood. The locally grown wood has also been suggested for certain types of construction, such as exterior siding in single-wall construction.

Judging from figures on specific gravity and shrinkage published by the Forest Products Laboratory in May 1959, Hawaii-grown toon appears equal to that grown elsewhere and should be excellent for the same high value end uses. Further studies of the physical properties are needed to verify these conclusions and determine other qualities. Recommended studies to determine its value as a cabinet wood include:

1. Lumber drying
2. Machining and finishing
3. Gluing

Recommended studies to determine its value as a construction wood include:

1. Natural resistance to decay and termites
2. Preservative treating
3. Paintability

In addition, studies of veneer cutting and drying may show a potential for high grade plywood for cabinet work and decorative paneling.

(4) Fraxinus uhdei--SHAMEL ASH

Shamel ash is another introduced species that has shown great promise in Hawaiian plantings. It has good form and growth rate and is reseeding naturally. Its wood appears excellent for those uses where a light colored hardwood of medium weight and strength is required, including furniture, cabinet work, general millwork, and decorative paneling.

Both actual and comparative strength properties are available from past studies at the Forest Products Laboratory, so potential users can judge the properties of this wood as compared to woods already in use. Shamel ash from Hawaii was found to be stronger and tougher than its specific gravity would indicate. It does not compare with white ash in these properties and therefore will not be as suitable for high-strength uses, such as in implement handles and athletic equipment. Because of its low shrinkage and high strength-to-weight ratio, however, it may have other special uses.

Information is needed on other physical properties of this species to help determine its suitability as a general cabinet wood and possible special high-value uses. The following studies are recommended:

1. Machining
2. Lumber drying
3. Natural resistance to decay and insects
4. Preservative treating
5. Veneer cutting and drying

(5) Cedrela odorata--CIGARBOX CEDRELA

Cigarbox cedrela is still another hardwood species that shows great promise in young plantings. Little timber is of merchantable size at present, but trial plantings look so encouraging that some exploratory milling has already been done. Cedrela odorata from tropical America and the West Indies is used for general millwork and paneling. If Hawaii-grown timber proves to be equally good, it will no doubt find similar uses. One or more outstanding physical properties may indicate special high-value end uses.

Studies of its strength and related properties are needed, in spite of limited present supplies, to measure its potential as a species for afforestation. Studies in the same detail as those made at the Forest Products Laboratory for shamel ash would be helpful. Also, the following physical properties should be determined:

1. Lumber drying
2. Machining and gluing
3. Natural resistance to decay and insects
4. Preservative treating
5. Paintability
6. Veneer cutting and drying

(6) _Sequoia sempervirens_--REDWOOD

A few forest areas in Hawaii have similar growing conditions to the redwood region of California. Uses for young-growth trees in Hawaii are not likely to be the same as those for the clear, all-heart redwood lumber now widely used in Hawaii. Clear, all-heart redwood is select material from old-growth timber. It is outstanding for house siding because of the grade as well as such desirable properties as low shrinkage, natural durability, paintability, and general good appearance. Plantation-grown redwood in Hawaii is most likely to yield lumber similar to the grades cut from young-growth redwood in California. There, this type of timber yields primarily utility items--2 x 4 framing, 2 x 6 and 2 x 8 decking, and common lumber. Plantation-grown redwood may also prove less valuable than old-growth lumber on other counts; lower natural resistance to decay and insects, and lower rating in paintability because of wide growth rings.

The strength and related properties of Hawaii-grown redwood were studied at the Forest Products Laboratory and reported in May of 1955. Small specimens of clear wood cut from this timber were found to be stronger than young-growth redwood from California, and in some strength properties superior to high specific gravity old-growth redwood. The shrinkage figures for the fast-grown plantation redwood were also favorable, even for longitudinal shrinkage, which is sometimes greater in fast-grown wood than in older, slower-grown wood.

Further study of strength properties is not advisable at this time because the Hawaiian timber is unlikely to yield much of the clear, select grades. Studies of lumber yields and grade are more needed than studies of the strength properties of clear wood specimens. Studies of other physical properties should be directed toward using plantation-grown redwood as a construction wood.

The following order is suggested:

1. Resistance to decay and insects
2. Preservative treating
3. Paintability
4. Lumber drying

(7) Grevillea robusta--SILK-OAK

Silk-oak appears to be one of the more promising timber species in Hawaii even though locally grown wood has not been studied. In Australia, native-grown wood is esteemed for cabinet work, plywood, and construction. Sawmilling trials in Hawaii have produced good material for paneling, furniture, and other uses. The wood is known in the lumber trade as silkyoak. The strength and related properties of Hawaii-grown silk-oak should be studied in about the same detail as has been done for shamel ash. Comparative strength figures would be helpful. Also, studies of physical properties are recommended in the following order:

1. Machining
2. Lumber drying
3. Natural resistance to decay and insects
4. Preservative treating, particularly with a clean preservative since probable end-uses will require painting or natural finishes
5. Paintability
6. Veneer cutting and drying

(8) Alnus nepalensis--NEPAL ALDER

Nepal alder appears to be a good wood for furniture, general cabinet work, and core stock, The strength and related properties should be studied as outlined for silk-oak.

(9) Flindersia brayleyana--BRAYLEY FLINDERSIA

This species, sometimes called Queensland-maple or maple silkwood, falls into the same classification with silk-oak and alder as to end uses, and studies as outlined for these two species are suggested.

Two or three species of pine and other softwoods such as araucarias are known to grow well in the Islands. Studies of the properties of these softwoods are needed to compare them with timber grown elsewhere to help determine their value in reforestation. Utilization of these softwoods will be principally in construction, so that information on strength properties will be important. As the industry develops, it will also need information on lumber yields and grades and on other properties related to construction uses.

Pines and other softwoods are planted on sites where hardwoods are difficult to grow.

RESEARCH AND ACTION NEEDED NOW, PLANNING NEEDED FOR THE FUTURE

To guide the development of a timber products industry in the Islands, these are the steps which must be taken now:

1. Survey the existing timber resource. This is being done.

2. Find out how Hawaii-grown timber can be used and how it compares in utility with other woods. This report tells where such information exists and where it is lacking. A follow-through is needed, with research on wood properties and the quality of logs and lumber grade yields.

3. Explore market opportunities. This is the objective of the economic study recommended by the 1959 Timber Conference. A start can be made anytime, without waiting for all timber quality and quantity information to become available.

4. Disseminate the results of the above research studies and promote the establishment of new industries. This is a job for industrial development agencies, both public and private.

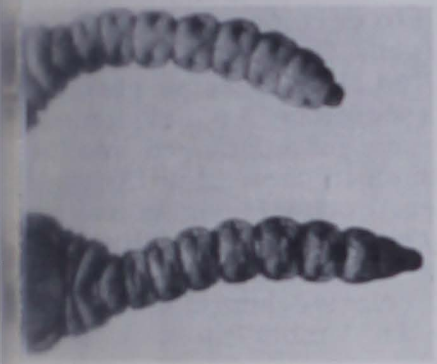
For the more distant future, further planning is needed. Several questions must be answered. In particular, Hawaii must decide what kind of a timber industry it wants. What it gets in the next few years will be dictated by the kind of timber that is ready to harvest. The demonstrated growth potential of the forest lands, however, suggests that other species may be introduced. Before much more tree planting is done, decision should be reached as to whether Hawaii will support a hardwood industry, a softwood industry, or both.

Entrance into offshore markets will afford a broad choice of species for reforestation. If they are not limited to local markets, land managers can plant the most profitable among suitable species. Each forest area can be planted to produce its greatest return. Site qualities of land available for reforestation will determine which species can be grown. Some sites, such as in the fringe area on the dry side of Molokai, will not grow good hardwoods, therefore pine is planted. On other sites, hardwoods will offer the best prospects for a high volume, high value forest.

For some time to come, softwoods grown in Hawaii will compete with high grade lumber from old-growth timber from the West Coast. Hardwood markets, on the other hand, do not discriminate in favor of old growth. Grade for grade, lumber from young-growth hardwood trees commands the same price as lumber from old-growth trees. The highest grades, though only part of the total yield, bring from $600 to $800 per thousand board feet, and, for certain sizes and grades of teak, true mahogany, black cherry, and black walnut, more than $1, 000. Lumber from fast-grown plantation teak is now accepted on a par with lumber from old-growth forests. The present price for teak in San Francisco is $1, 300 per thousand board feet.

Hawaii enjoys a unique opportunity: to guide the development of a new industry to produce wood for trade and local use and at the same time, through multiple-use management, to enhance the watershed, recreation, and other resource values of its forest lands. Timber quality studies play an important role in bringing about this development. They will aid in selecting the timber species with the greatest potential for profitable returns.

EETLE LARVAE



ORER LARVAE

Miscellaneous Paper No. 49
Berkeley, California
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE
June - 1960

BEETLES and BURNED TIMBER

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Forest fires in 1959 killed more an 800 million board feet of merchant- le timber in California. The fires ve long since cooled. The loss of tim- r promises to continue. Why? For o primary reasons: (1) Fire-injured es often give rise to bark beetle out- eaks in nearby green timber; (2) fire- lled trees are favored hosts of wood ring insects, an important cause of ood deterioration.

The danger from bark beetles in 60 is greatest in pine timber of the ixed conifer belt, where some of the ost disastrous fires occurred. Damage om wood borers, on the other hand, n be expected in practically all kinds fire-killed timber throughout the State.

ark Beetles

Bark beetles pose the worst threat, pecially this year. Climatic conditions California have favored the beetles for e past two years. In some parts of the ate these insects are already extremely undant, and everywhere beetle popula- ons are high. Therefore, the tendency r infestations to "snowball" soon after a re is stronger than normal. Extensive ee-killing is likely. And since most rk beetles transmit wood-staining fungi, ey also help to reduce wood quality in e trees they kill.

Enemy number one is the western pine beetle in ponderosa pine. Number two is the mountain pine beetle in sugar pine. Both are abetted by the red turpentine beetle, which commonly attacks the base of weakened trees. In Douglas-fir, the flatheaded fir borer and the Douglas-fir beetle are the most destructive.

Bark beetle outbreaks after fires follow no set pattern. Usually, though, they start in weakened trees--not dead ones. Beetles that breed in fire-damaged trees move into surrounding undamaged timber or into islands of green timber skipped by the fire. If a fire occurs early in the season, concentrations of beetles generally begin to develop around it the same year. But if a fire occurs late in the season, the beetles will not start to concentrate until the next summer. In either case the beetles usually require two years after the fire to reach their maximum destructiveness.

About half of California's major timber fires in 1959 took place in the spring or summer, the remainder in the fall. Around some of the early burns, infestations started that year. The late ones remained uninfested overwinter, but attacks can be expected to start this spring, and infestations to build up for the next 18 months.

How can we keep these buildups from happening? The best answer is to beat the beetles to the punch by logging trees that are potential beetle producers before they become infested.

The potential for attack is closely tied in with degree of defoliation and cambium injury from fire. Both types of injury should be taken into account in marking burned timber for salvage logging. Several studies show that percent defoliation is a fairly good indicator of the probability of beetle-caused loss in ponderosa pine that survives a fire:

Percent defoliation:	Percent of trees killed by beetles
0-25	0-15
25-50	13-14
50-75	19-42
75-100	45-87

Sometimes it is impractical to log the trees the beetles will attack. And salvage-logging often must leave small or inaccessible trees that may become infested. Then we may have to fell the infested trees and spray them with insecticides or burn them to prevent infestations from spreading.

Infested trees may be hard to spot the first summer after a fire because beetle-killed and fire-killed trees look much alike. Later, differences are easier to see. It is important to keep looking for infested trees.

Wood Borers

Wood borers breed only in dead trees and are not quite as prolific as bark beetles, but directly or indirectly, they do much to destroy wood quality. The larvae bore through the wood, creating "worm holes" which degrade lumber values. They also introduce stain and decay-producing organisms which ultimately make the wood unfit for use.

The most destructive wood borers belong to two families of beetles: the roundheaded borers and the flatheaded borers. Both groups contain a great many species, some of which are attracted to fire-killed timber even before the fire is out.

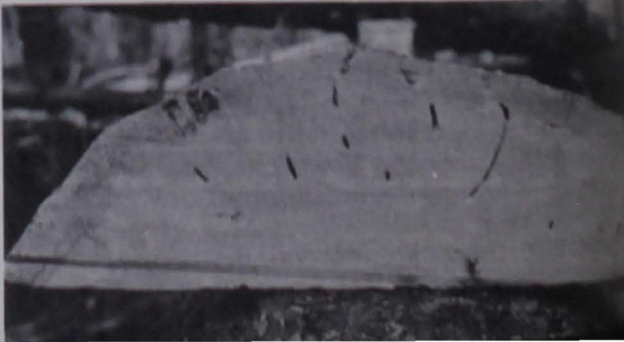
With wood borers, as with bark beetles, prompt logging will help keep damage to a minimum. This is especially important for timber killed in summer fires. On unlogged 1959 summer burns, for example, borers already will be well established. But timber killed in the fall probably will not be hit until late this spring.

Once borers are established, they often continue to develop after the trees have been logged. Consequently, the logs should be milled as rapidly as possible. A few borers continue to develop even after the logs are manufactured into lumber. One species in particular (Arhopalus productus (Lec.)) often becomes a serious problem in fire-killed Douglas-fir. Kiln-drying for 6 to 8 hours at 140° F. and 70 to 80 percent relative humidity will kill these borers in timber up to 2 inches thick.

To Sum Up

1. Damage from bark beetles and wood boring insects can be expected to be especially severe this year and next around 1959 timber fires.
2. Logging fire-weakened trees before they are infested by bark beetles, and fire-killed trees before they are riddled by borers will help keep losses down.
3. Close surveillance of burned timber lands and prompt detection of bark beetle outbreaks will help show where insect control is needed. Report infestations through the cooperative forest pest detection survey.

--R. E. Stevens and R. C. Hall



DAMAGE BY WOOD BORERS ▷

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No. 50 August 1960

WHAT DO PEOPLE KNOW ABOUT FIRE PREVENTION?

By
Craig C. Chandler
Pacific Southwest Forest and Range Experiment Station

and

James B. Davis
California Division of Forestry

You have to be carefully taught. Although this is the title to a song from a recent stage play and motion picture, it could well be the basis of our forest fire prevention effort. More and more we are finding that education is the key to success in forest fire prevention. But it must be a careful education, and we are finding that half an education may be no better than none. This is because a successful fire prevention campaign is one that does two things --

It teaches why we must be careful with fire.
It teaches how to be careful with fire.

Simple, isn't it? But the prevention man faces several problems in trying to apply these two easy maxims. The first problem in organizing a prevention campaign is how to divide the total effort between the "why" and the "how."

After this question has been answered, the prevention man faces the problem of what to teach. To catch and hold attention, information must be important, clear, and fresh. If the presentation is too technical, people are confused. Too simple or trivial information, on the other hand, can be boring or downright insulting.

These problems can be solved only if we know what the forest-using public already knows and believes about fire prevention. It becomes obvious that if we are to be good teachers we need to know a great many more facts about the people we are trying to teach.

To supply these facts is the object of research being conducted by the University of Southern California School of Public Administration under a contract with the Pacific Southwest Forest and Range Experiment Station. A recent progress report prepared by the University of Southern California staff offers some interesting reading for those concerned with forest fire prevention. 1/

This report discussed primarily the part of the research which sought to devise various kinds of questions that could be used in future surveys of the fire prevention knowledge and attitudes of various forest-using groups. Secondary aims of the study were to try various methods of administering questionnaires in the field and to develop a program for rapid processing of questionnaire results by electronic computors.

Eight questionnaire forms were tested. Five of these were designed for forest recreationists and three for summer home owners. Some of the forms were used by a trained interview team from the University of Southern California, some by forest fire prevention personnel with the assistance of a trained University interviewer. Still others were used by prevention personnel aided only with written instructions. The next step was the establishment of an analysis program for the IBM 650 computing equipment at the University.

The University of Southern California researchers now have the tools they need, including interview techniques, IBM procedures, and a stockpile of questions for the next phase of the test--a large-scale survey of California hunters that should provide a definite answer to the question "What do people know about fire prevention?" 2/

In addition, an important bonus benefit was obtained from the preliminary tests. The progress report goes to some length to point out that the results of the eight test questionnaires should be accepted with caution. Each of the questionnaires was designed and administered differently. Consequently, the data could not be pooled, and no rigorous statistical treatment was possible. Nevertheless the answers are quite informative. Certain patterns of response run consistently through the whole series. A subjective appraisal of the 2,645 questionnaires that were completed shows some leads that may be of direct benefit to fire prevention program directors.

Men scored consistently better than women in fire prevention knowledge. This is hardly surprising in view of the subject matter.

1/ Herrmann, W. W., 1959. Progress Report on Research Activities Relevant to Human Behavioral Aspects of Forest Fire Prevention. University of Southern California, School of Public Administration. 188 pp. (processed).

2/ A two percent survey of California hunters will be conducted by the University of Southern California School of Public Administration during 1960, using a systematic sample of hunting license records provided by the California Department of Fish and Game. This study is being financed jointly by the U. S. Forest Service and the California State Division of Forestry.

People in the age bracket from 25 to 50 had the most correct information on fire prevention. Under age 25 the problem seemed to be one of lack of information, and over 50 one of misinformation.

Except among workers in lumbering and forestry, who scored consistently high, knowledge of fire prevention paralleled quite closely general educational and intellectual level as indicated by occupation. One rather disturbing fact is that agricultural occupations, which should be exposed to more fire prevention information than many other classes, scored lower than people in professional, sales, clerical, and service categories. In view of the exceptionally high level of knowledge in the lumber industry, it appears that we have failed to reach the rancher-farmer with our present fire prevention program.

Length of residence in California did not affect the scores, but length of residence in the local area had a very marked effect. This seems to shoot holes in the often expressed idea that it is the newcomers to California who are our biggest fire problem.

Local residents had more fire prevention knowledge than visitors. Local residents who neither hunt nor fish did better on the recreationist questionnaires than did hunters from outside the area. Yet statistics on fire causes show that 60 percent of California's man-caused fires are started by local residents. It would appear that we have a situation where the local resident knows all about fire prevention but doesn't much care, while the city visitors have a very good attitude towards prevention but just don't know what to do to prevent fires.

Perhaps some of the problems implicit in the above paragraph can be explained by an analysis of the sources of information. It was immediately apparent from such an analyses that people get little "how to do it" information from the organized, mass media fire prevention campaigns. This should be accepted as a statement of fact and not an implied criticism of the mass media programs. The primary intent of any large-scale advertising program is to condition attitudes and make people aware of a product or situation, not to impart specific knowledge. In arousing a desire to "prevent forest fires," the mass media campaigns have been outstandingly successful with the audience for which they were designed.

In any event, if we exclude "common sense," an often listed source of both information and misinformation, the analysis shows that more correct and less incorrect information was obtained from talking with other people than from any other source. This seemed to be true regardless of whether the people were our own employees, parents, friends, or the gas station attendant. Written material, such as newspapers, magazines, and signs, occupied an intermediate position, being the source of more correct and less incorrect information than radio and television but less than that obtained through individual contacts.

Looking at the content of individual questions, one fact stood out like a sore thumb. We have apparently failed to get acceptance of the necessity for hazard reduction around buildings. This was in the top five most commonly missed questions in every questionnaire where it appeared. All of the alternative answers were for clearance requirements less than adequate, and of the residents who answered correctly, half of them merely guessed that the largest clearance listed was the one they ought to put down.

There are two other general areas of misinformation that may be of practical importance. The California burning permit regulations were not well known by local residents. It may be argued that because nearly everyone who missed these questions thought that the requirements were more strict than they actually are, the level of knowledge in this area is no cause for concern. However, it is unlikely that anyone who believes that a burning permit is required for all fires for all 12 months of the year has ever applied for a permit. Therefore, the misinformation about permits probably means that the individuals concerned have either never needed a permit or never bothered to obtain one.

The campfire permit of the Forest Service also appears to be a subject of misinformation. About one-third of the people sampled thought the permit was valid on private as well as public land within a national forest, and 10 percent thought it was a blanket permit, good on any land in the state.

There are other areas that may pose particular prevention problems as indicated by these preliminary surveys, but in most cases the questions need to be revised to give significant guides for action.

The six words, "You have to be carefully taught," were extremely successful for their writers. There is good reason to believe their application, guided by the facts about what people know (or don't know) about fire prevention, will be equally successful for us.

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MISCELLANEOUS PAPER

No. 51 August 1960

WHAT PEOPLE THINK ABOUT FIRE LAW ENFORCEMENT

by

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and

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There is an old story about a farmer that had a very intelligent, hardworking mule. However, always before giving it a command he hit the mule between the eyes with a baseball bat. Not because the mule needed discipline, but because this was the only way the farmer knew to get the mule's attention.

In a sense this may be the problem that we face when we try to get compliance with forest fire laws in California. Are people paying attention to fire safety rules, and, if not should we make more use of our legal baseball bats to insure their attention? A recent study may give us some clues. [1]

The study was conducted by the University of Southern California under contract to the Pacific Southwest Forest and Range Experiment Station. Its objective was to develop the framework for a larger-scale research study to determine the attitude of the public towards law enforcement. Though primarily a search for satisfactory experimental design, this pilot test points out some important differences between violators and non-violators as a group. The results show that the average fire law violator is an honest, intelligent citizen, well aware of the importance of fire prevention, but that we have just failed to get his attention on specific fire regulations.

Since the study sought to find differences in attitude and knowledge between fire law violators and non-violators, Dr. Herrmann prepared two lists of persons. Names and addresses were obtained from lists of property owners on file at the Big Bear sheriff's sub-station, from Arrowhead District Ranger Station, and from license numbers of cars driven by forest motorists.

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[1] Herrmann, W. W., 1960, A Research Design for the Evaluation of Attitudinal Aspects of Fire Law Enforcement. Univ. of So. Calif. Sch. of Pub. Admin., 48 pp. (processed).

The names of fire law violators were taken from the law enforcement records of the San Bernardino National Forest. The violators came from 66 towns and cities throughout southern and central California. Their distribution was about what could be expected, taking into consideration population and distance, with two possible exceptions. No violators were "out-of-state" residents, and only 11 percent of the violators were forest residents despite the fact that nearly half of the use and slightly more than half of the man-caused fires on the San Bernardino forest come from local residents. Of 675 people in the combined lists, 256 non-violators and 42 violators agreed to cooperate in the study.

Admittedly the 298 persons sampled is a very small percentage of the San Bernardino Forest's visitors, let alone California forest visitors. Yet the study can give us some pretty good ideas on how people feel about fire law enforcement in southern California. In addition it gives us some information on the makeup of the fire law violator group.

What Kind of Laws Are Violated?

For the most part the laws were not broken because of a lack of what could be called "common sense." They were rather specific regulations that needed to be learned and some of them actually involved forestry jargon or shop talk. For example, the most persistent violation concerned fire closure areas. The USC researchers found "closed area" means many things to many people.

The 138 violations were broken down in the following way:

Closed area	62
Improper use of fire	44
Smoking illegally .	9
Trespass	3
Miscellaneous	20

The miscellaneous group includes such items as dumping hot ashes, blasting without a permit, and inadequate spark arrestors.

Do Forest Users Know The Law?

Most people think that it is difficult to keep from violating fire laws. Thirty-one percent of the non-violators and 53 percent of the violators said that they did not have enough information about laws or rules to avoid breaking them.

When asked "Do you think it is easy or difficult to get information concerning forest fire prevention rules?" both groups agreed that it was pretty difficult. Forty-two percent of the non-violators and 48 percent of the violators thought that it was either difficult to get information or had never tried to get it.

Even more striking, 53 percent of the non-violators and 71 percent of the violators believed that fire prevention laws are not known to most other people.

What Do People Think About Fire Laws?

Even though they don't know what the laws are and can't seem to find out, most people questioned think that fire laws are as important as traffic laws. This applies for both violators and non-violators. People were definite about this point; only about 5 percent said they didn't know about the relative importance, and some of the non-violators tended to consider fire laws even more important than traffic laws. When asked "Which would you observe more carefully?" most people said they would observe fire laws "about the same" as they would traffic laws.

How Do People Feel About Fire Law Enforcement?

Reaction to enforcement depends to a degree on whether one is a violator or a non-violator. The great majority--87 percent-- of the non-violators thought that there should be more law enforcement. The violators were not quite so positive about this; many had no opinion, but less than half thought that there should be less enforcement.

Almost all of the non-violators believed that people contacted by a forest ranger regarding a violation are treated fairly. Only 3 percent thought the treatment might be severe. Of the violators, however, 30 percent said they had not been treated fairly. Although most thought their treatment had been fair, some believed that it had been severe.

Who Violates Forest Fire Laws?

The survey indicates that most fire law violators were well-meaning persons who did not realize that they were making a mistake. However, some made "well-intentioned mistakes" outside the forest, too. When asked "Have you received any traffic citations in the last two years?" fire law violators answering yes outnumbered non-violators three to one. Again, this seems to be a matter of lack of awareness, rather than disregard for law. For example, when asked to name some of the California National Forests they had visited, over half the violators named Yosemite, Joshua Tree, or other National or State parks. Only 5 percent of the non-violators group make this mistake. Similarly, more than half of the violators said they had never seen a burned-over area even though such a sight is difficult to miss in southern California mountains.

To Sum It All Up

We find that San Bernardino National Forest visitors and residents think that fire laws are important. However, they think that it is difficult to get enough information to keep from breaking the law.

Despite an active fire prevention program which has had a notable effect in increasing public consciousness of the fire problem, we have not been very successful in calling people's attention to the fire laws. This is particularly true with the violator group.

In forest fire prevention there appears to be a real need to improve our educational methods. The baseball bat method was the only technique the farmer knew. We hope that continued research can find a more satisfactory method for foresters.

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No. 52 August 1960

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DISEASES THREATEN FOREST NURSERIES

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Richard S. Smith, Research Assistant
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Federal, state, and private for- ers have begun a stepped up refores- on program in California. They have sted the output of tree seedlings and planning even greater production in est nurseries. Are tree diseases a eat to these plans? Disease losses e been noticed in some California series recently. Nurserymen took ck and aggressive action to check the ses, and special research was started the Forest Service nursery at cerville in 1959, soon after losses e noticed, to identify the troublesome gi and to test various fungicides for eir control. Results from control dies are not yet available, but the ntification studies suggest that:

1. Damping-off and root rot fungi urseries may require more than usual ention.

2. Reforestation programs should rd against introducing new pathogens forest areas.

E DESTRUCTIVE AGENTS

Damping-off and root rot fungi are en inhabitants of forest nursery soils. se fungi vary widely in their ability damage specific hosts and in their re- tance to cultural and chemical control thods. As the first essential job of re- rch, the fungi in the Placerville

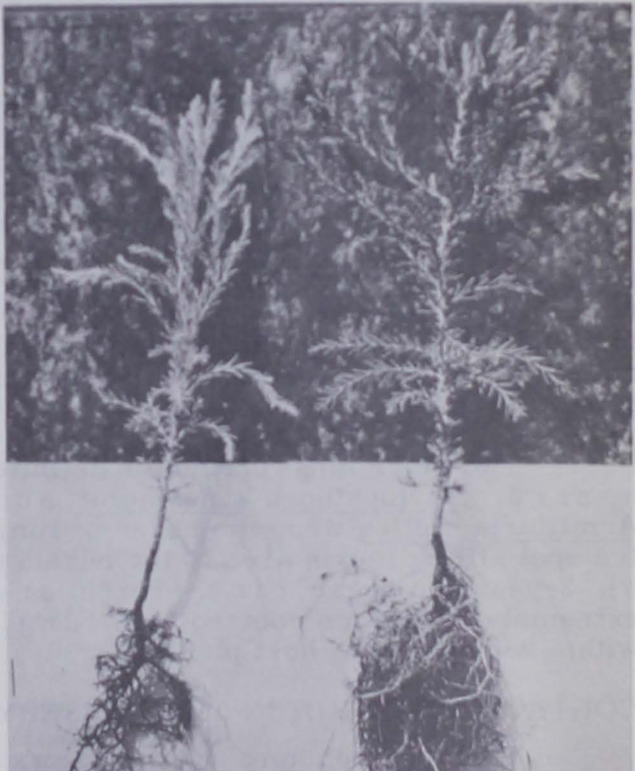

Figure 1.--Charcoal root rot of 2-year-old Sequoia gigantea, left, caused by Sclerotium bataticola.

nursery soils and in the diseased plants were identified by culturing them in the laboratory.

The charcoal root rot fungus, Macrophomina phaseoli (Sclerotium bataticola), proved to be the chief cause of high mortality in 1-year-old sugar pine, Douglas-fir, and giant sequoia. This fungus (fig. 1) is favored by high soil temperatures. It attacks several hundred genera of plants. Recent reports throughout the State indicate that it is assuming more importance as a root pathogen in forest nurseries and in agricultural crops.

Some of the identified diseases will require further study to evaluate their role as tree-killers. These include several forms of Fusarium oxysporum and F. solani isolated from the diseased plants and the nursery soil. Inoculation of healthy plants with these isolates may show them to be a cause of mortality. But fungi of this genus are highly host-specific, and clones of these species are common saprophytes found as secondary invaders in the infected roots of many diseased plants. Hence their isolation from diseased tissue is not an indication of pathogenicity. Rhizoctonia solani, Phoma sp., and Pythium were also isolated from the diseased roots, but with low enough frequency that their present role in the disease complex is important primarily in cases of damping-off.

Two other fungi present a definite hazard. Phytophthora cinnamomi and Armillaria mellea were the cause of limited spot killing in one area of the nursery on 2-year-old sugar pine. Both are extremely dangerous root-rotting fungi with a wide range of host plants.

CONTROL MEASURES IN THE NURSERY

The phytophthora root rot was considered to be so great a threat that a three-pronged eradication program was put into effect. First all the 2-year-old sugar pine in and around the diseased areas were condemned and destroyed. Then chemical eradication of the pathogen in the infested soil was attempted on the half-acre containing the infectio centers. Just before planting, a so fumigant of 57 percent methyl bromid and 43 percent chloropicrin (Pathofume was applied by shank injection at a ra equivalent to 450 pounds per acre (fig. 1 The area was then sealed under polyethylene for 24 hours. This high dosage of fumigant was used to insure eradication of the pathogen. Finally, all sugar pine planting stock from the uninfected nursery areas are being followed in the field. Those that die will be checked t see if phytophthora root rot is the cause of death. If it is, immediate spot fumigation will be carried out in the field.

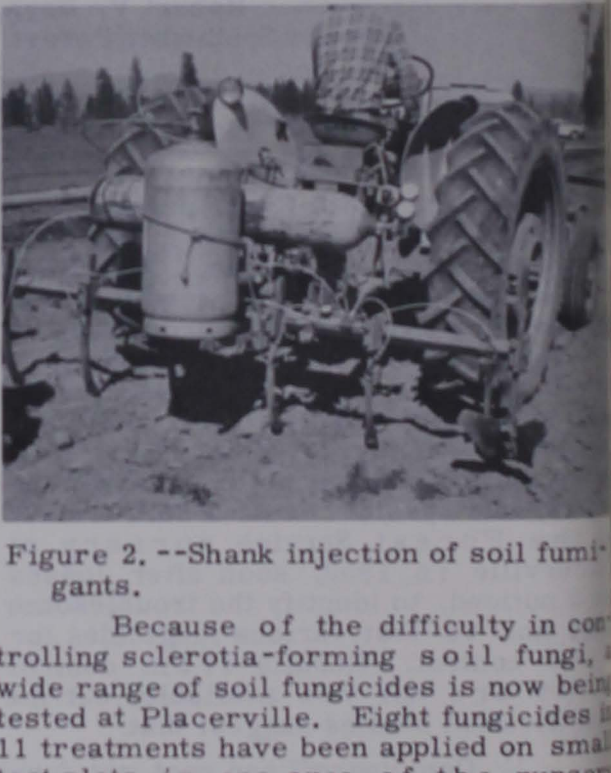

Figure 2. --Shank injection of soil fumigants.

Because of the difficulty in controlling sclerotia-forming soil fungi, a wide range of soil fungicides is now being tested at Placerville. Eight fungicides in 11 treatments have been applied on small test plots in one area of the nursery where damage was prevalent in 195 (fig. 3). The individual treatments were applied to 50-square-foot plots, each of which is surrounded by a buffer strip which was fumigated with a high dosage (435 pounds per acre) of chloropicrin. The buffer strips were used to lessen the chance of contamination from the surrounding non-treated soil. The treated areas have been seeded with sugar pine, and the results from these tests will be evaluated as to efficacy of control and economy of application.

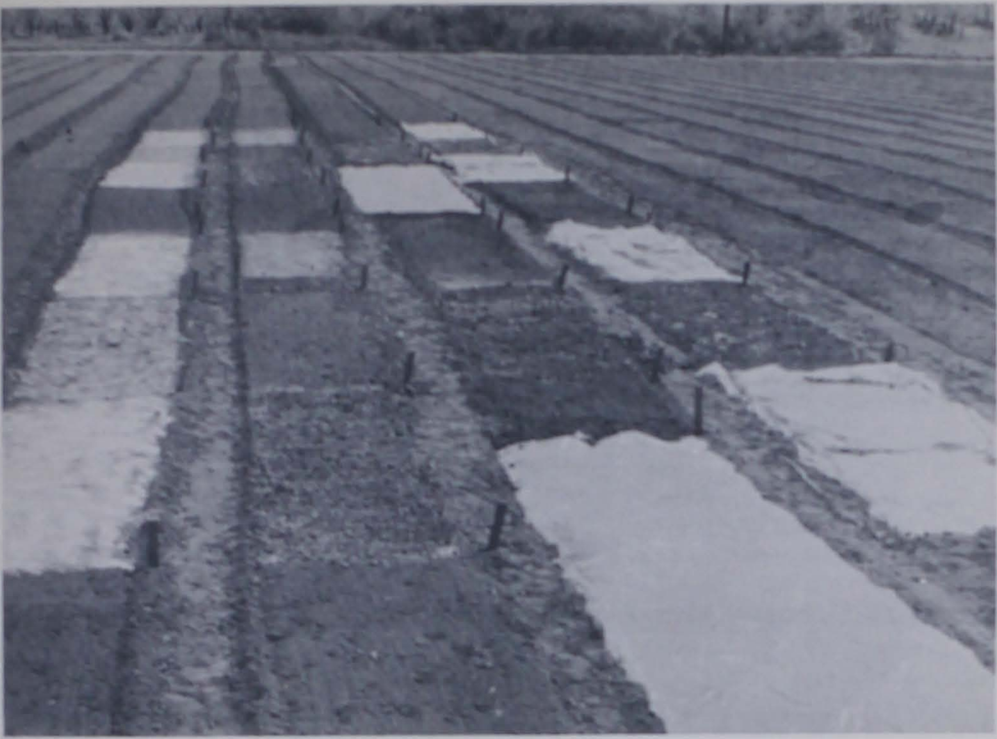

Figure 3. --Experimental plots at Placerville nursery.

SULTING PROBLEMS IN THE FIELD

The nurserymen can measure ease losses, but only by the mortality l the obvious decline of planting stock l in the nursery beds. Initial stages infection in seedlings are not easily ected except by close laboratory mination. But loss in the nursery is y one facet of the overall problem uing from nursery diseases.

Plants with a seriously impaired ot system may not show symptoms of ease while they are growing under the al environmental conditions of the nur- ry. However, when these seedlings e planted out in the field under less orable environmental conditions, the eased root system is unable to function iciently and the seedling dies.

Losses of seedlings in the nursery e serious enough; the introduction of a w and virulent pathogen into the for- ted areas of California would be disas- ous. One of the most effective means introducing these destructive agents to a new area is by planting diseased rsery stock.

Phytophthora cinnamomi is a very destructive, introduced organism with a reported host range of some 100 plants, many of which are forest trees. This organism is a causal agent of the little leaf disease in the southern pines and has been found to be the cause of mortality of *Pinus radiata* and *Cupressus macrocarpa* in New Zealand. So far, it has not been found in forest areas of California.

Armillaria mellea, another of the fungi isolated from the nursery stock, is pathogenic on many western coniferous forest trees. Douglas-fir is so susceptible to this pathogen that it has been used as a test plant in determining the presence of the organism in questionable soils.

The problem becomes even more serious when we realize that once these pathogens are introduced, there are no known methods of controlling them economically in a forested area.

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No. 53 October 1960

CALIFORNIA MANZANITA FOR SMOKING PIPES[1]

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Since supplies of genuine brierwood have been largely cut off from the American smoking-pipe industry by war conditions, manufacturers have been seeking sources of suitable domestic woods. Recently the production of manzanita pipe blocks has begun on a commercial scale, and a lively interest in the new industry has developed among both pipe manufacturers and California landowners. It is hoped that this article will serve the dual purpose of acquainting pipe manufacturers with manzanita and of informing interested Californians about the history and recent developments in the pipe-wood trade.

Production of Brierwood Pipe Blocks[2]

The wood of the root burl of tree heath (*Erica arborea*), commonly called brierwood, has been favored for pipe bowls since about 1860. This dwarf tree is distributed to some extent throughout all the Mediterranean countries, and in normal times most of these countries have exported varying quantities of the wood to the United States in the form of blocks from which pipes are manufactured.

The pipe-block industry started in France and spread to Italy, which maintained dominance in the trade until the first decade of the present century. At that time the depletion of the brierwood stands forced manufacturers of blocks to seek new supplies in Algeria. Regeneration has brought the stands of France and Italy back to importance in the past decade. France led in exports of blocks to this country in 1929, 1930, and 1931, and since then Italy has been our chief source of supply until the present war period.

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[1] Originally issued as Technical Note No. 18, April 24, 1942.

[2] Burls are cut into small blocks, each one of a size suitable for the manufacture of a single pipe bowl.

Algeria produced about two-thirds of the world supply of brierwood during the period 1919 to 1928, with a maximum production of about 22,000 tons of green burls in 1924. Her average production was 13,200 tons from 1910 to 1937. Against this figure the estimated capacity of the country for growing burls is only 11,000 tons, based on a rotation of 45 years (average age of utilization). Obviously, exploitation has gone beyond the sustained-yield basis for the whole area in spite of the fact that most of the producing land is publicly owned, with cutting controlled under a leasing system. It is probably safe to assume that overcutting has been as extensive in France and Italy as in Algeria. The industry has evidently exploited the best of the virgin stands of Mediterranean brierwood and has fallen back on second growth. With lack of cutting control and with increasing world demand it is likely that the world supply of tree heath burls will eventually be seriously diminished.

Alternative Woods for Pipe Bowls

The American smoking-pipe industry, having an estimated current demand for 40 million blocks annually, has turned its interest to domestic woods since war conditions have cut off supplies of brierwood. With the Mediterranean resource badly depleted, this temporary stress in the pipe wood market may offer an opportunity for the introduction of permanent alternatives rather than temporary substitutes for brierwood.

Alternative woods for pipe bowls must have the same qualities that are found in the burl wood of tree heath; (1) resistance to charring, (2) absence of disagreeable odor in charring, (3) resistance to checking under heat, (4) strength, (5) attractive figure (flame grain, if possible), (6) reception of coloring with stain, (7) ability to take polish. The tangled fiber structure of burl wood supplies the features of attractive figure and homogeneous strength properties. In addition to technical qualities a merchantable wood must occur in burls of good quality in quantities that are accessible enough to repay establishment of block-cutting mills.

California possesses one widespread member of its extensive brush fields that has satisfied the above requirements to the extent that three factories have been established for pipe-block cutting. This is manzanita (*Arctostaphylos* spp.). The burl-forming species of this genus produce wood that is not quite so dense as brierwood but is entirely satisfactory as regards smoking quality and figure.

Comparison of Manzanita and Tree Heath

There are a number of similarities between the burl-forming manzanitas and tree heath. Both are major constituents of closely related brush types. The maqui of the Mediterranean region, in which tree heath occurs, is a dense shrub type, similar in aspect to the Pacific Coast chaparral, where manzanitas make up a large share of the vegetation. Species of scrub oak are common associates of each. These shrub types grow under like climatic conditions, in a temperate region with summer drought and winter rainfall. They are found primarily in coastal and foothill areas. Often they will invade former forest sites, after fire or cutting has destroyed the tree cover.

Manzanita and tree heath are related to each other botanically, belonging to the Ericaceae, or heath family. Both are hardy shrubs, capable of growing on poor soils and of withstanding drought. However, although the leaf forms are both typical of drought-resisting plants, they are quite different in appearance. Tree heath has narrow, linear leaves arranged in whorls of three or four, and manzanita has thick, leathery, alternate leaves.

Another common characteristic, and a very important one, is their ability to form burls. The burl is an aggregation of short branchlets fused into a complex, patterned mass of wood. At its surface the branchlets are terminated by dormant buds, which are capable of sprouting when the main trunk is destroyed or the plant undergoes fire or other injury. However, this does not mean that the burl formation itself is a reaction of the plant to fire or cutting, although these may affect its size or shape. The best burls for the purpose of pipe manufacture are those which have grown to merchantable size in areas where no fires have occurred. The incipient burl appears in very young plants and seems to be a normal development characteristic of certain species, including tree heath and the sprouting manzanitas. In studies made on tree heath in Algeria no pathological source of the formation was discovered. The initial cause of the swelling, which appears at the base of the stem in the young plant, is still unknown. A comparison of photographs of seedlings and young plants of sprouting manzanitas and tree heath, showing the growth of the burl, discloses a parallel development in the two groups.

In appearance, the wood of manzanita burl is much like brier burl; it also has the flame pattern, one of the desirable qualities of brierwood.

In Algeria the optimum age for the utilization of brier burls is 45 years for the country as a whole (40 years on the coast and in the foothills and 50 years in the higher mountains). Tree heath of this age produces burls of 4½ to 9 pounds measuring approximately 6 to 8 inches in diameter. Manzanita burls probably develop more rapidly. The following figures were obtained from measurement of one well-formed manzanita burl 12 inches in diameter taken from the coastal area of California:

Annual rings from center	Diameter (inches)
5	0.55
10	1.15
15	3.30
20	6.80
25	9.25
30	11.60
31	12.00

Range of Manzanita in California

The manzanitas can be divided into two broad classes: (1) those that are killed outright by fire, and (2) those that sprout from a woody root-crown after fire has gone through the stand. It is the latter group in which we are interested, as they are the burl-forming species. The sprouting manzanitas, common constituents of the chaparral in California, are widely distributed throughout the Coast Ranges, the mountains of southern California, and the Sierra Nevada foothills. The most important of these is the complex of species including woolly manzanita (Arctostaphylos tomentosa), Eastwood manzanita (A. glandulosa), and closely allied forms, occurring in the north and south Coast Ranges and in southern California. Shagbark manzanita (A. rudis), although limited to western Santa Barbara County and the southwestern corner of San Luis Obispo County, is an important burl-forming species. In the Sierra Nevada foothills Indian manzanita (A. mewukka) forms burls that might also be used commercially. Greenleaf manzanita (A. patula), a sprouting species of the Sierra Nevada and north Coast Ranges, is not included in the accompanying map (Fig. 1) showing the distribution of manzanitas in California, because in the areas so far investigated the burls of this species are apparently of minor importance. 3/

Distributions of the species shown on the map are taken largely from data collected by the vegetation type survey of California. 4/ However, with the exception of portions of Napa, Lake, and Mendocino Counties,

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3/ Other burl-forming species of California that might bear investigation as pipe material are the silktassels (Garrya spp.), California snowbell (Styrax californica), coast rhododendron (Rhododendron californicum), and several of the ceanothus species, Palmer ceanothus (C. palmeri), spiny ceanothus (C. spinosus), Lemmon ceanothus (C. lemmonii), and woollyleaf ceanothus (C. tomentosus). Although burl-forming, these shrubs may not prove to be commercially valuable. Chamise (Adenostoma fasciculatum), widely distributed throughout the chaparral areas of the State, appears to be unimportant because of the small size of the burls. Another shrub, redshanks (Adenostoma sparsifolium), forms large burls and might repay further study, although one operator has reported that the wood is too hard to work profitably. For ranges of these species, consult McMinn, An Illustrated Manual of California Shrubs (4).

4/ See Wieslander, A Vegetation Type Map of California (8).

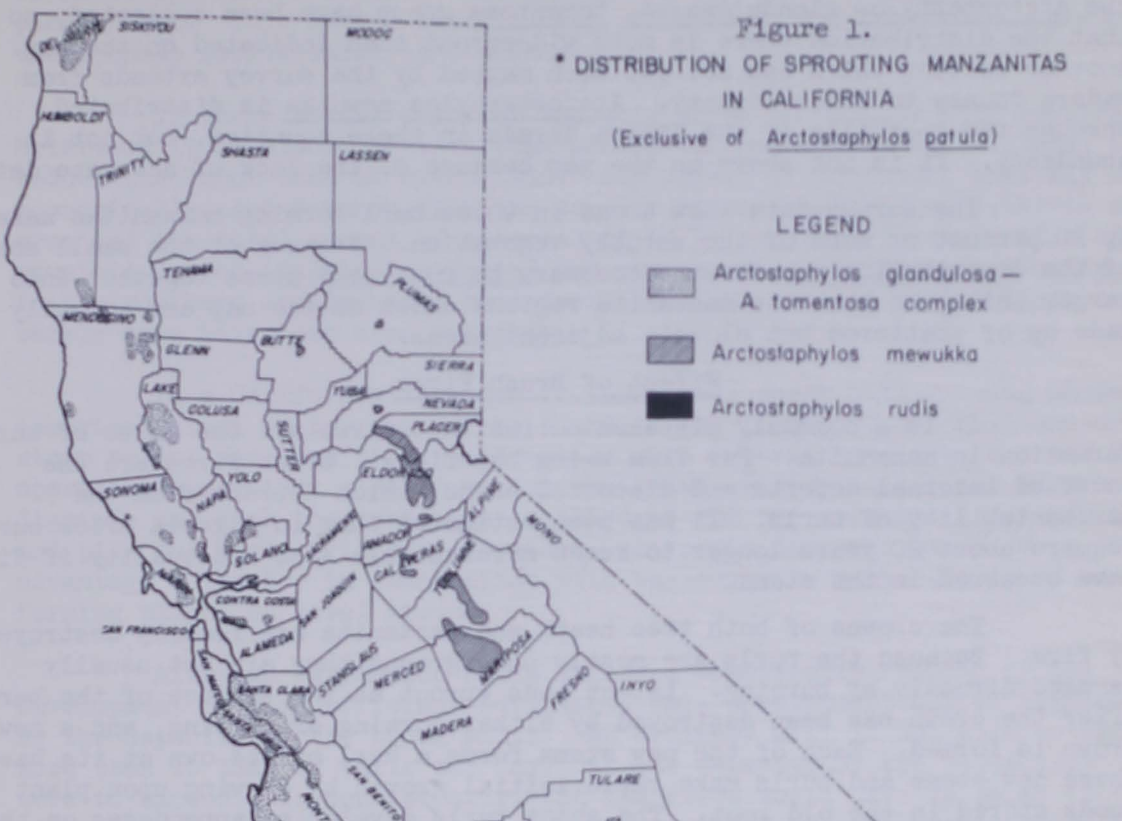
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
LASSEN
TEHAMA
PLUMAS
MENDOCINO
GLENN
BUTTE
SIERRA
LAKE
COLUSA
YUBA
NEVADA
PLACER
SUTTER
YOLO
SONOMA
NAPA
EL DORADO
ALPINE
MONO
SOLANO
SACRAMENTO
AMADOR
CALAVERAS
TUOLUMNE
MARIN
CONTRA COSTA
SAN JOAQUIN
SAN FRANCISCO
ALAMEDA
SAN MATEO
STANISLAUS
MARIPOSA
SANTA CLARA
MERCED
SANTA CRUZ
INYO
FRESNO
MADERA
SAN BENITO
MONTEREY
TULARE
KINGS
SAN LUIS OBISPO
KERN
SAN BERNARDINO
SANTA BARBARA
VENTURA
LOS ANGELES
RIVERSIDE
ORANGE
SAN DIEGO
IMPERIAL

Figure 1.

* DISTRIBUTION OF SPROUTING MANZANITAS IN CALIFORNIA

(Exclusive of Arctostaphylos patula)

LEGEND

☐ Arctostaphylos glandulosa — A. tomentosa complex

▨ Arctostaphylos mewukka

■ Arctostaphylos rudis

* Data incomplete for north Coast Ranges; see text.

the survey did not cover the north Coast Ranges, and data for this section are taken from locations where herbarium specimens of the manzanitas of the Arctostaphylos glandulosa--A. tomentosa group have been collected, so that the distribution there is more widespread than indicated on the map. Another section which has not yet been mapped by the survey extends from Madera County to Tulare County. Arctostaphylos mewukka is distributed through the foothills of the Sierra Nevada in these counties, but not in abundance. It is not shown on the map because of the lack of accurate data.

The survey data show areas in which burl-forming manzanitas make up 20 percent or more of the shrubby vegetation. Because of the small scale of the distribution map it was necessary to run these areas together into larger units, so that the manzanita regions shown on the map are actually made up of scattered but closely adjacent areas.

Effect of Brush Fires

It is a commonly mistaken notion that fires are the cause of burl formation in manzanita. Far from being beneficial, brush fires are the cause of internal defects and distorted shape, which detract from the merchantability of burls. It has been estimated that in Algeria brier burls require about 20 years longer to reach merchantable size and quality if fires have occurred in the stand.

The crowns of both tree heath and manzanita are readily destroyed by fire. Because the burls are mostly underground they are not usually damaged directly by burning. Latent buds sprout at the surface of the burl after the crown has been destroyed by either burning or cutting, and a new crown is formed. Each of the new stems forms a burl of its own at its base. These new stems and burls make rapid initial growth by drawing upon plant foods stored in the old root. The shoot burls develop as appendages on the original burl, forming extremely odd shapes that are difficult to reduce to pipe blocks without extraordinary waste. The distorted growth sometimes encloses rocks, which are damaging to the mill saws.

Although the external living portions of burls of fire-killed crowns remain green enough to sprout, the internal wood is exposed to drying, which causes shrinkage checks and cracks offering avenues of invasion for destructive fungi and insects. Thus, on areas that have been burned over and have recovered by sprouting, many burls appear sound on the surface but may prove to be defective when opened. The merchantability of such burls depends on the amount of sound wood surrounding the defect. After examination of manzanita in the coast region Garland and Wieslander 5/ have estimated that burls may be expected to contain enough sound wood to make them merchantable, if the stand has not been badly burned in the past 25 or 30 years.

Extraction of Burls

The extraction of burls from the land is mostly hand work in Algeria. Hunters precede the crews and select vigorous-looking plants having no more than three closely set stems. The crews dig the earth from the burl to ascertain whether it is merchantable. If it is a desirable burl, the stems are cut off, the earth is dug away, and the

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5/ A. E. Wieslander, In charge, Forest Survey Division, California Forest and Range Experiment Station.

roots are cut off. Most of the work is done with a short-handled pickax or mattock. The burls are removed from the forest to a temporary dump by pack animal. This method has proved profitable in the Mediterranean area, where cheap native labor is obtainable.

If there is any hope for domestic woods to compete with genuine brierwood it is almost certain that mechanical means must be developed to reduce the labor cost of extraction. The amount of equipment that may be economically used depends upon the density of merchantable material in an area and the total amount of material to be extracted. In extraction of mountain laurel (Kalmia latifolia) and rhododendron (Rhododendron maximum) in the southern Appalachians hand-operated stump pullers of the block and tackle type have been used recently.

In a California location in sandy soil where burl-forming manzanita comprised about 20 percent of the stand, a gasoline-powered cable-and-drum stump puller has been used to advantage with a three-man crew, one man to operate the machine; another to cut the crown, partly expose the burl by digging, and hook the cable; and a third to cut the root and branch stubs and pile the burls (Fig. 2). Another California operator has used to advantage a tractor in combination with bulldozer in dense stands of burl-forming plants on level ground.

Although extraction costs might be drastically reduced by the development of more efficient equipment, this development may be limited by the capacity of the block mills. An ordinary mill is not able to use more than 10 tons of burls per day. If the capacity of the woods crew were to exceed this consistently, the operation would have to be an intermittent one and additional cost would be incurred in large-scale storage of burls.

Burls of both brierwood and manzanita check and split in the whole piece because of shrinkage at the slightest drying. For this reason care must be taken to retard drying from the time the crowns are cut off until the burls are cut into blocks. In the woods the piles of burls are covered with green branches cut from the plants to protect them from the sun. In storage, the piles must be wet down periodically with water. In Algeria piles of burls are covered with ferns, grass, or other green leaves. They may not be left in the piles for more than 9 months without danger of decay and stain.

Manufacture of Blocks

The amount of usable pipe-block material that can be cut from a ton of burls depends on the amount of defect in the burls and on the skill of the workmen. The highest average amount recovered by the best workers in Algeria is about 35 percent of the green weight; the average for all Algerian brierwood operations is about 20 to 25 percent. Probably recovery in manzanita does not average so high as this except for burls that have not been damaged by fire.

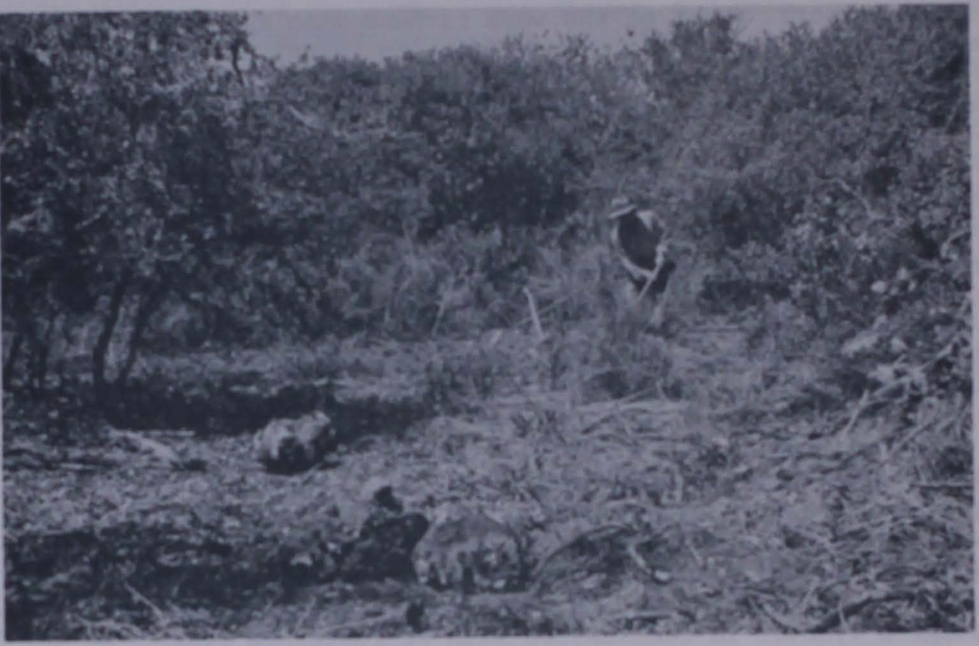

Figure 2a.--Opening in brush field in Monterey County where burls have been extracted. Worker is chopping off excess branches and roots. Note burls in foreground ready to be hauled to pipe-block mill.

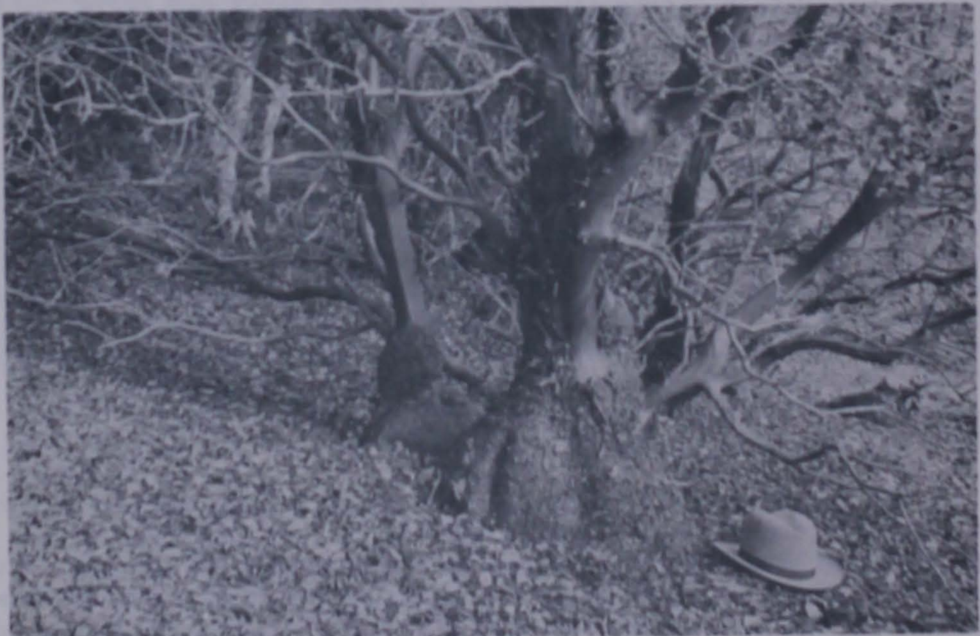

Figure 2b.--Burl formation at the base of Eastwood manzanita shrub in Santa Cruz County. This is larger than normal but fairly typical of quality found in some areas.

Twenty-three different types and sizes of pipe blocks are recognized in the industry. In typical European mills, there are rows of identical circular table saws, each with an operator. An operator is given a burl or a piece of burl and is charged with cutting out the best possible combination of block types, at the same time attempting to cut the pattern of the flame grain so that it is parallel with the axis of the bowl. Each operator performs the whole operation of turning out completely sawed blocks.

Some mills in this country have been designed on the "line production" principle. The material passes from one saw to the next, each operator making a different cut. The first saw cuts the burl into slabs; the next cuts the slabs into strips; the next cuts the strips into blocks; and the last one cuts off part of the block to give it the shape of the pipe model for which the grain is most suited. In this cutting method there is much less possibility of obtaining blocks that will show a well-patterned flame grain on the finished pipe.

Pipe blocks are sold according to quality, as well as size and shape. Brier pipes retail at 25 cents and up. There is a large market for pipes selling at less than a dollar. Such pipes usually have small defects that may be filled in finishing and hidden by applying a dark stain. Expensive pipes are made from relatively rare blocks that are without flaws and are cut from the burl so that the grain produces a symmetrical pattern. The normal pipe-block market requires a balance in the supply of low- and high-grade material. Burls need not be without defect to be merchantable; however, they must be sound enough to yield a reasonable proportion of volume in usable blocks. Under present market conditions it is possible that large quantities of "clean" burl material would not be in so much demand as material that yields different grades of blocks, since the market for high-grade blocks is limited.

Before the present war period the average price paid by American pipe makers for brier was approximately 2 cents per block. Some shipments of genuine brier were still coming into the country in 1941, but the cost to the manufacturer had been increased about fourfold because of shipping and insurance rates. Pipe makers were then paying an average of 6 cents each for domestic blocks that were suitable substitutes for brier.

Extent of the Pipe-block Industry in the United States

In the summer of 1941 seven pipe-block mills in the southern Appalachians, using burls of mountain laurel (Kalmia latifolia) and rhododendron (Rhododendron maximum), were producing an amount estimated at one-fourth of the demand of the American pipe industry. The wood of these plants is evidently entirely suitable for pipes; however, the supply of burls in the area may not be large enough to satisfy the demands of the present mills. Only part of the plants produce burls, and these only at an advanced age. The burl-forming plants occur in thickets or clumps scattered in areas not exceeding two or three hundred acres. Scouting for the plants appears to be an important element in the Appalachian industry. Burl prices at the mill in 1941 were $10 to $12 per ton, of which about $1 to $1.25 represents stumpage.

In midsummer of 1941 two relatively large block mills were established in California to cut manzanita grown in Santa Cruz and Monterey Counties. Both these mills are associated with large pipe companies. More recently another plant has been established in this area and there were plans for a fourth. There has been a rather active competition among mills for the contracted supply of burls, but the price of merchantable burls delivered has not exceeded about $12 per ton. At least one mill operator has asked for 10-year contracts for exclusive purchase rights on some manzanita land.

This new California industry has centered around Watsonville. There are probably other fairly extensive areas of merchantable burl in the range of the sprouting manzanitas, but at this time little is known of their extent and accessibility.

One mill began operating in the Los Angeles area in 1941, using the burl of redshanks (*Adenostoma sparsifolium*). It is reported that this operation was discontinued because of manufacturing difficulties. Burls are readily available, of good quality, and suitable for pipes, but the operator has found the wood to be too hard to work into pipe blocks profitably.

Future Possibilities for Manzanita

With the burl resource of the Appalachian region apparently being exploited to its limit and producing only one-fourth of the industrial requirements, it is probable that the use of manzanita for pipe blocks will expand somewhat and will continue at least until normal Mediterranean trade is resumed. If trade practices return to the same basis as before the war, this new California industry will fade away in favor of the less costly brierwood. The possibility remains that the supplies of genuine brierwood will be diminished in the future to such an extent that the smoking-pipe industry will again turn to manzanita as a permanent resource. Furthermore, there are several possible developments in the trade which might tend to make manzanita an effective competitor of brierwood and thus stabilize the present industry.

The primary factor that would keep manzanita in the market is the reduction in production costs to bring the price of blocks more in line with that of the imported product. It is probable that some reduction in costs could be attained by further mechanization of burl extraction, increase in milling efficiency, and better organization between extraction and milling. Costs of pipe blocks could be reduced if markets for other manzanita products could be developed. Some burls of choice quality and large size might be more valuable for manufacture into novelties, turnery, small furniture, and even veneer for figured panels. These burls could be made to bear a proportionately greater share of the cost of extraction than pipe burls from the same area. The stems of manzanita plants are now wasted or, at best, used as firewood. These might well be made into rustic furniture and novelties. The use of stems or large pieces of burl depends upon the working out of seasoning methods that will bring the material to usable dryness without checking. The techniques of chemical seasoning recently developed at the Forest Products Laboratory, Madison, Wisconsin, should prove helpful in this regard. Means of utilizing the sawdust and trimmings that constitute 70 to 80 percent of pipe burls warrant research because of the irregular fiber structure, which is unique among commercial woods. Chemical investigations might disclose value in the soluble materials which are extracted from the blocks when they are boiled. Profitable utilization of any manzanita material which is not used for pipe blocks tends to spread the cost of production and lower the cost of the blocks.

The terms "brier" and "brierwood" have long been associated with good smoking quality in the minds of the pipe-smoking public. For this reason pipe manufacturers will probably encounter some sales resistance in the introduction of alternative pipe woods. The logical solution to this problem would seem to be a trade promotion campaign to extol the virtues of manzanita. If the smoking quality of the wood is, in fact, not inferior to "genuine brier," it is possible that the market could be led to demand "genuine manzanita" for smoking pipes. In this event, even though the cost per block were a few cents higher than imported wood after the war, the manzanita block industry could be at least partly sustained. A domestic source of pipe wood should be attractive to manufacturers, since they could more easily estimate future supplies and, to some extent, develop supplies to meet their demands.

Although there have been mentioned some possibilities that might result in a permanent manzanita-block industry, it would be unwise for any owner of land bearing merchantable burls to anticipate a certain sale, since the industry is thus far localized. It would be advisable, however, for owners of such land to use extra care to protect them from fire. Some landowners are now reaping the benefits of forest-fire protection, while others have found that fire damage has prevented the sale of many tons of burls.

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No. 54 November 1960

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1960 FIRE WEATHER SEVERITY IN CALIFORNIA

By Arthur R. Pirsko, Research Forester
Division of Forest Fire Research

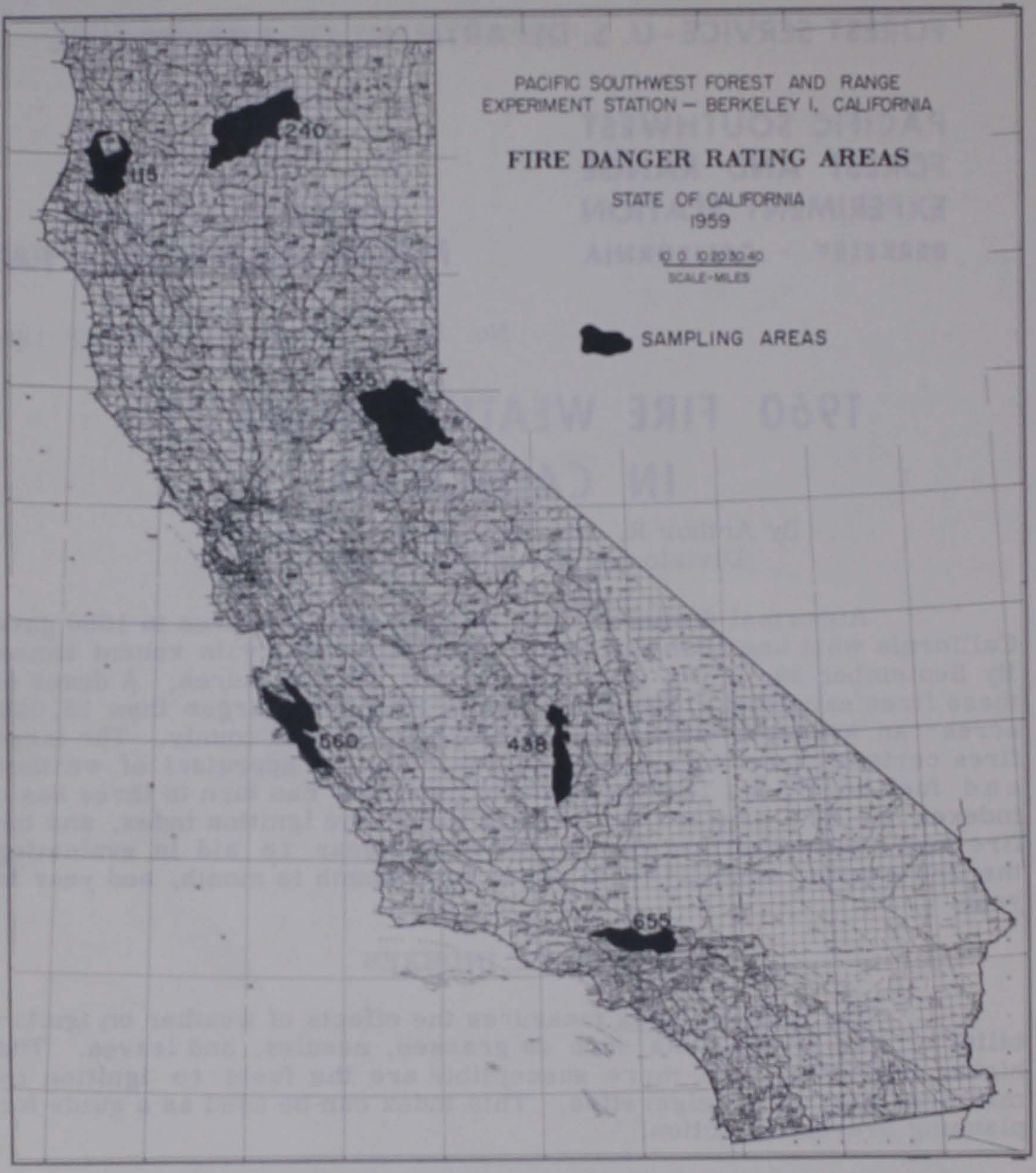
Abnormal dryness and extreme temperatures in 1960 gave California what has been called the worst fire history in recent times. By September 30, 5,100 fires had burned 250,000 acres. A dozen of these fires exceeded 3,500 acres each. Four were larger than 28,000 acres--an area the size of San Francisco city and county. The large fires certainly point to a severe season. For an appraisal of weather and fuel conditions leading to such fires, we can turn to three basic indexes of fire danger--the burning index, the ignition index, and the fire load index--the last two developed this year to aid in evaluating the fire weather severity from day to day, month to month, and year to year.

THE BASIC INDEXES

The ignition index measures the effects of weather on ignitability of fine forest fuels such as grasses, needles, and leaves. The higher this index, the more susceptible are the fuels to ignition by matches, sparks, or cigarettes. This index can be used as a guide for planning prevention action.

The burning index measures the effect of weather on the difficulty of fire control. It is based on how fast a fire spreads and how intensely the fire will burn. This index is used as a guide for planning fire suppression action.

The fire load index combines the ignition index and burning index into a single number summarizing the effects of weather on ignitability, rate of spread, and intensity of burning. This summary characteristic of the fire load index is then an expression of the potential fire prevention and suppression job necessary to meet the threat caused by weather. Within each fire danger rating area, the fire load index for a given period can be compared with the index for this period in other years, or under average conditions. When accumulated for the entire fire season, it indicates the total relative severity of the fire weather each year.


PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION — BERKELEY I, CALIFORNIA
FIRE DANGER RATING AREAS
STATE OF CALIFORNIA
1959
10 0 10 20 30 40
SCALE-MILES
SAMPLING AREAS
240
115
335
560
438
655

Location of sampling areas used to rate severity of 1960 season.

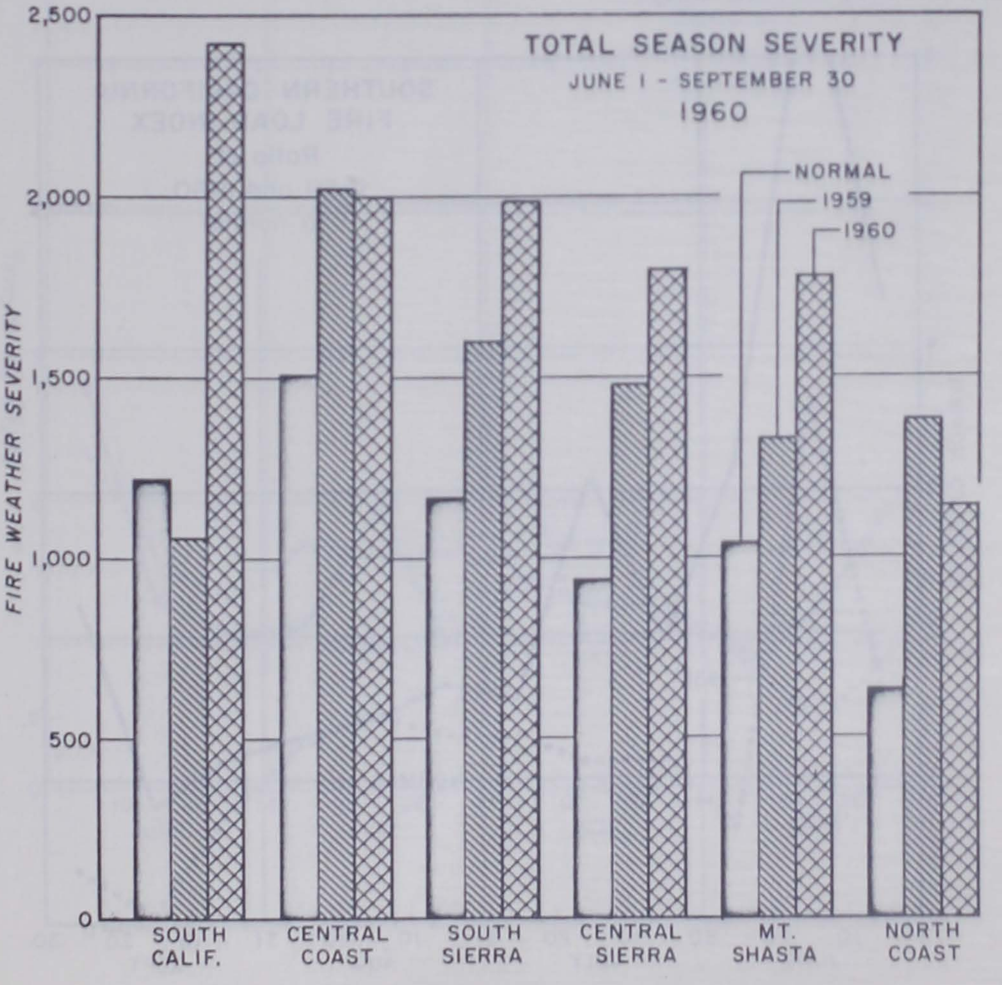
THE 1960 SEASON

To rate weather conditions for California in 1960, the seasonal severity indexes were compiled for six fire-danger rating areas in California wildlands.

General area	County	National Forest	Fuel type and fire danger rating area
North Coast	Humboldt	Six Rivers	Timber, FDR 115
Mount Shasta	Shasta-Siskiyou	Shasta-Trinity	Timber, FDR 240
Central Sierra	El Dorado	Eldorado	Timber, FDR 335
South Sierra	Tulare	Sequoia	Brush, FDR 438
Central Coast	Monterey	Los Padres	Brush, FDR 560
Southern California	Los Angeles	Angeles	Brush, FDR 655

SEASONAL FIRE WEATHER SEVERITY

For the season as a whole, weather conditions imposed a greater than normal load on protection organizations in all sample areas in 1960. The fire weather was more severe in 1960 than in 1959 in all areas except the Central Coast and North Coast. In terms of average conditions, both southern California and the Central Sierra had a seasonal severity twice normal. This double load is reflected in the major fires in these areas and corresponding severe burning conditions.

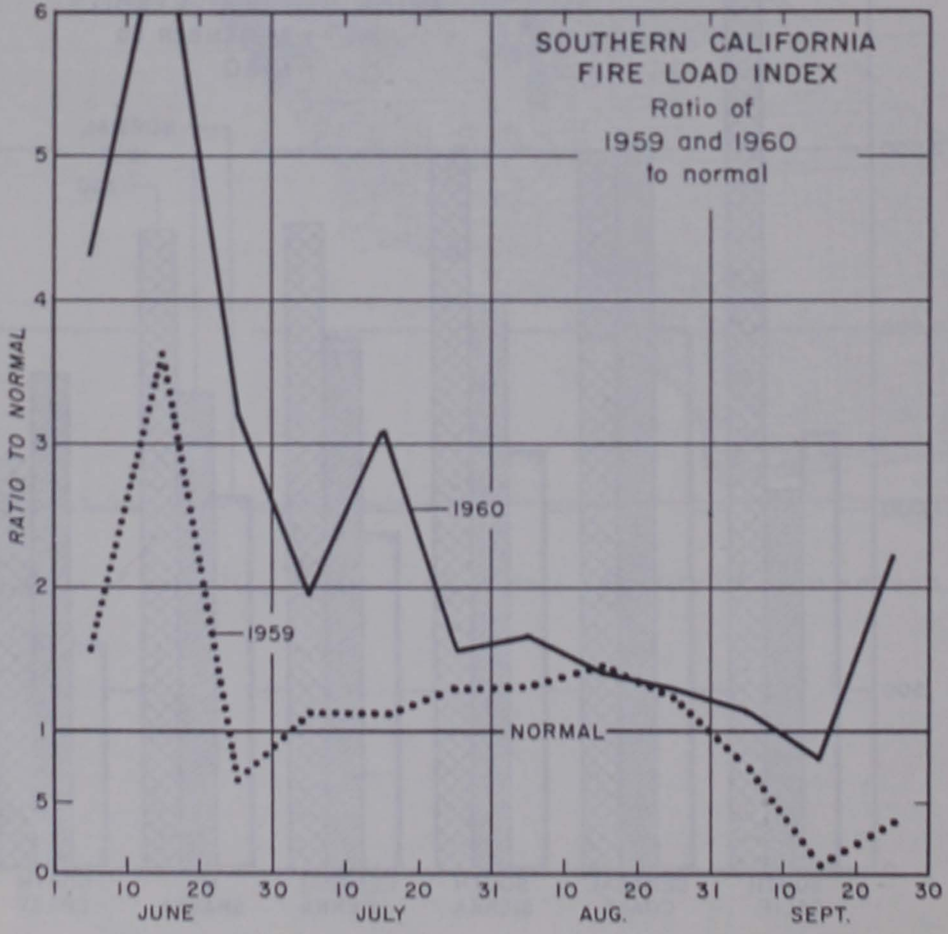


FIRE LOAD INDEXES BY 10-DAY PERIODS

In southern California, the 1960 season jumped off to a fast start in June because of high temperatures and low humidities. The resulting low fuel moistures boosted the fire load index to a peak of more than 6 times normal.

By mid-July, the vegetation was as dry as it normally is at the beginning of September, which is usually the worst month of the fire season in southern California. At this time another heat wave pushed the fire load index to a second peak--more than three times normal for this period. During this period the Angeles National Forest had the 14,737-acre Polecat fire, the 23,170-acre Johnstone fire and the 27,500-acre Magic Mountain fire. The adjoining Los Padres National Forest had the 11,870-acre White Mountain fire.

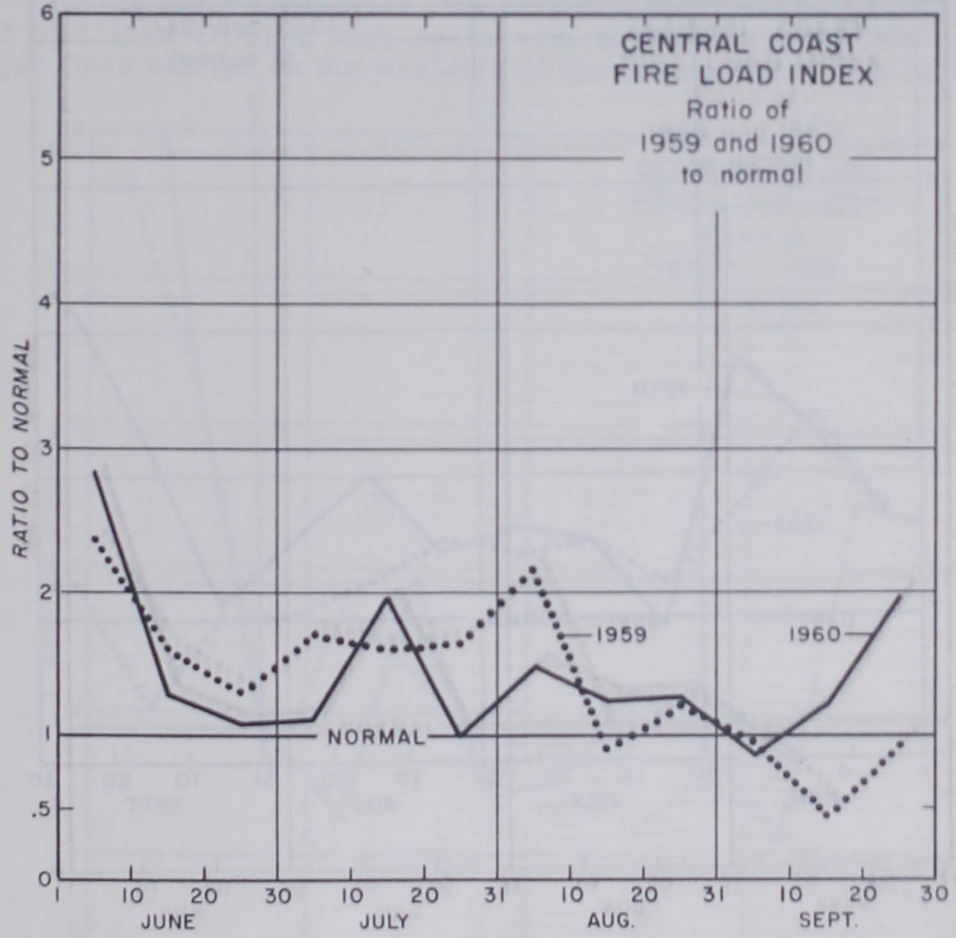
It must be remembered that these fire load graphs show the ratio of the actual index for a given 10-day period to the normal index for that period. Since the normal fire load increases as the season progresses, an index 6 times normal in June is not twice one that is 3 times normal in mid-July.



The Central Coast also had an above normal fire load index in June. By mid-June the Los Padres National Forest already had a 400-acre fire. Toward the end of the month the index lowered to almost normal conditions.

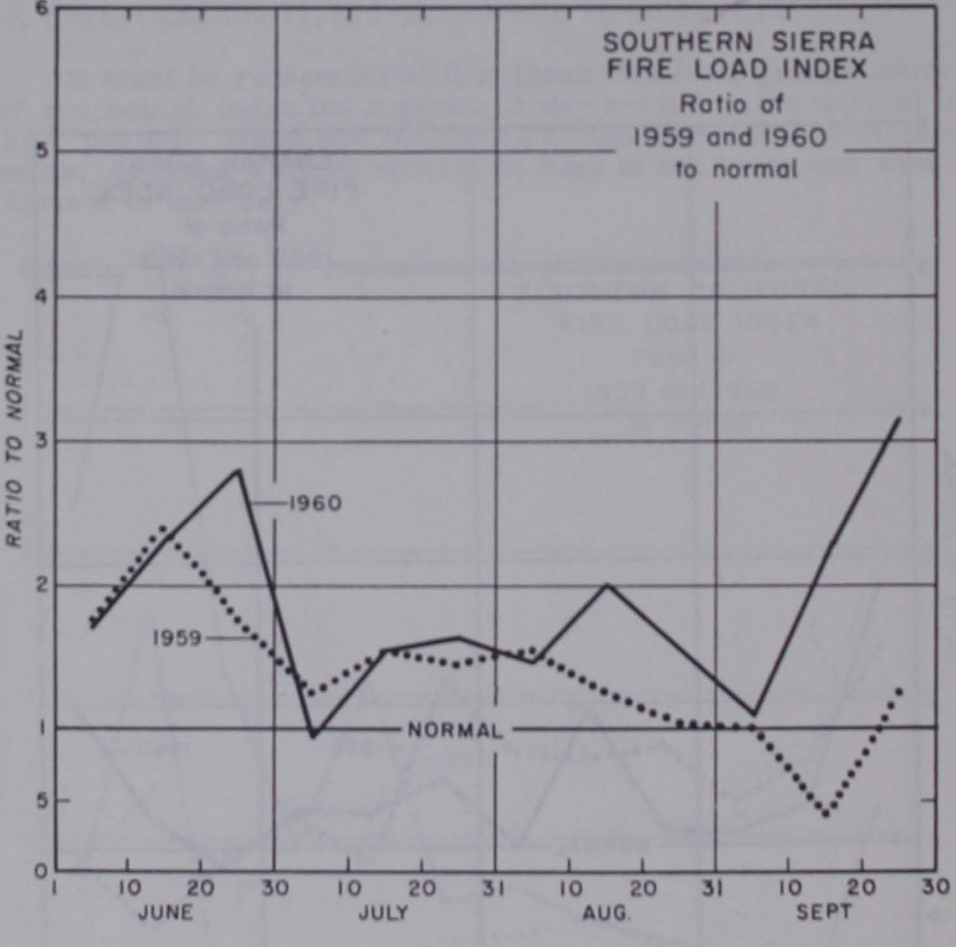
The July 1960 heat wave, however, jumped the fire load index to two times normal. In this general area, the California Division of Forestry fought the Weferling fire which burned over 50,000 acres of valuable watershed land and threatened the Hearst Castle State Park before it was controlled.

After July, the potential fire load gradually eased off toward normal. The almost normal conditions lasted until early September. Lack of autumn rains helped push the index back toward twice normal in late September.



In the southern Sierra the fire load index reached almost 2-1/2 times normal in late June 1960. At this time Sequoia National Park lost 4,950 acres in the Tunnel Rock fire, and the Coffee Camp fire in Sequoia National Forest, burned 1,100 acres.

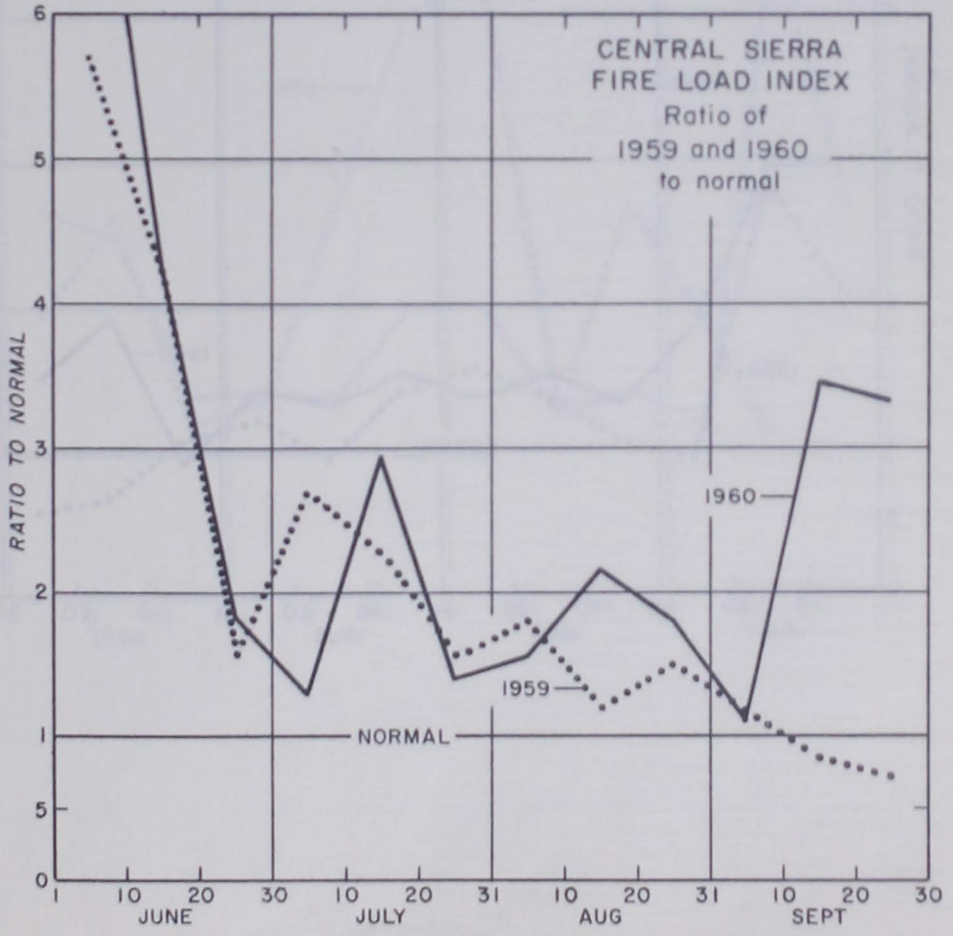
As in most parts of the State, the fire load index climbed during September because of extended dry weather, warm temperatures, and fall winds. In contrast, 1959, with a general fall rain, had a fire load index below normal by mid-September in this area.



The central Sierra had above normal fire load indexes throughout all of the 1960 season. June started with an index 6 times normal. In July, the mid-month index was 3 times normal. At this time the Stanislaus National Forest had the 2,000 acre Flora fire in a timbered area. Fire-weather conditions eased off toward the end of July but were still worse than normal.

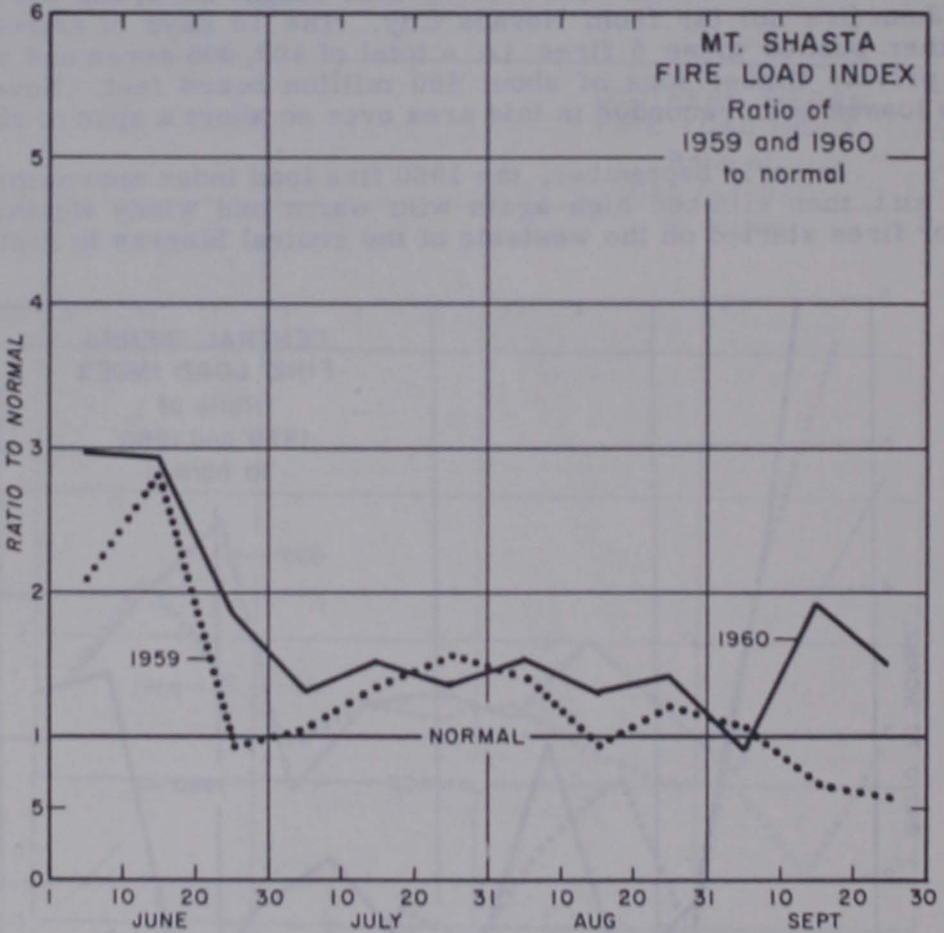
By mid-August the index again moved far above normal. The 10-day average was 2-1/4 times normal. The 4,020-acre Mosquito fire, the 3,605-acre Virgilia fire, the 44,000-acre Donner Ridge fire, and the 45,900-acre Volcano (Homestake Mine) fire started during this period on the Plumas and Tahoe National Forests. At the same time, the California Division of Forestry also fought the 5,000-acre North San Juan fire not far from Nevada City. The 10 days of extreme fire weather pushed these 5 fires to a total of 102,000 acres and a public and private timber loss of about 450 million board feet. Never have such losses been recorded in this area over so short a span of time.

In early September, the 1960 fire load index approached normal but then climbed high again with warm and windy weather. No major fires started on the westside of the central Sierras in September.



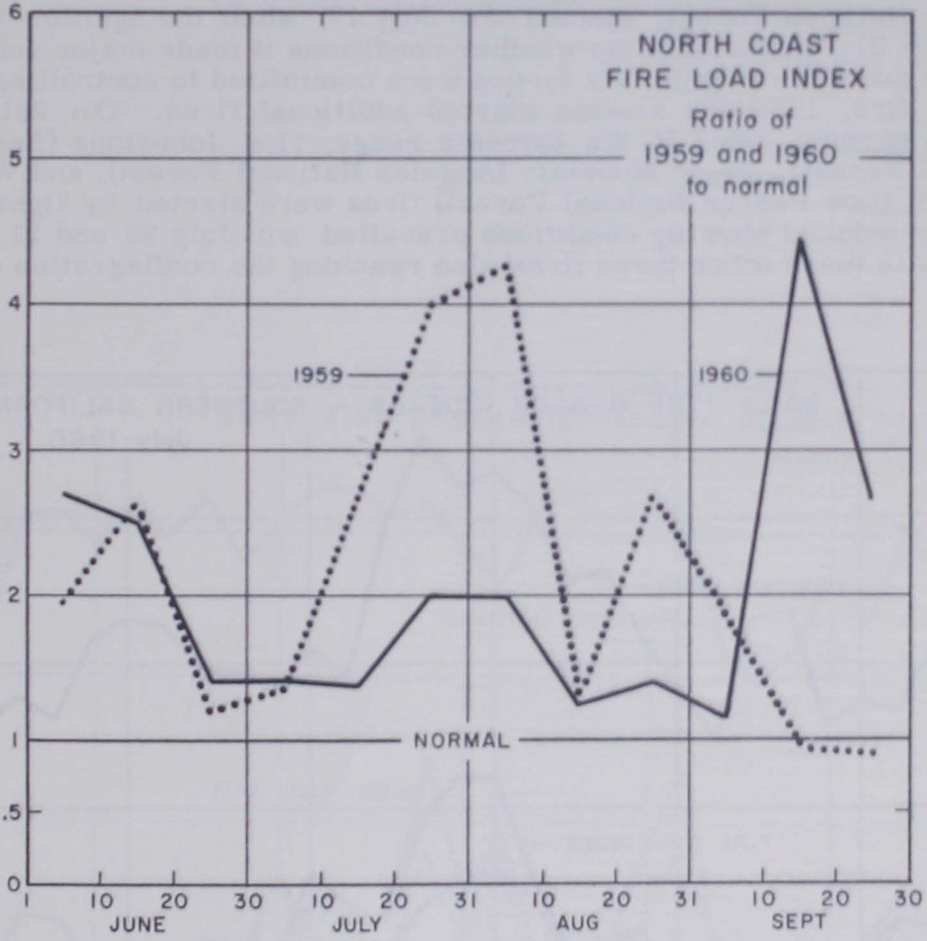
Northern California around Mount Shasta had above normal fire load indexes throughout 1960 except for the first 10 days in September. Weather conditions, however, were not as severe as throughout the rest of the State.

As in most of California, the Mount Shasta area experienced the worst fire weather in June and late September, but no major fires were started during these periods.



On the north California coast three major peaks of above normal fire load indexes occurred in 1960. Early June, late July, and late September had fire weather conditions more severe than is normally expected during these periods. A few timber fires did occur during the last two peaks but all were controlled at less than a thousand acres.

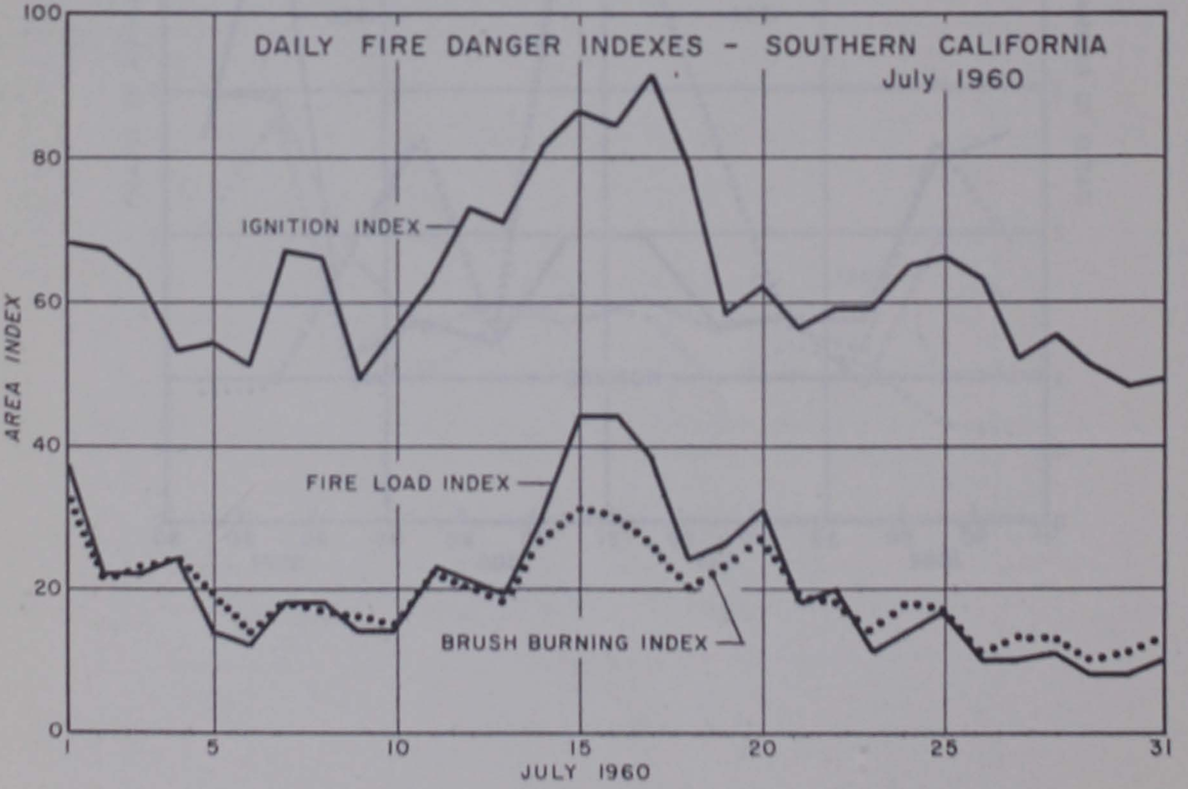
The potential for fire was high in late September because of continued dry weather, and the month closed with the fire load index almost three times normal.



DAILY FIRE DANGER

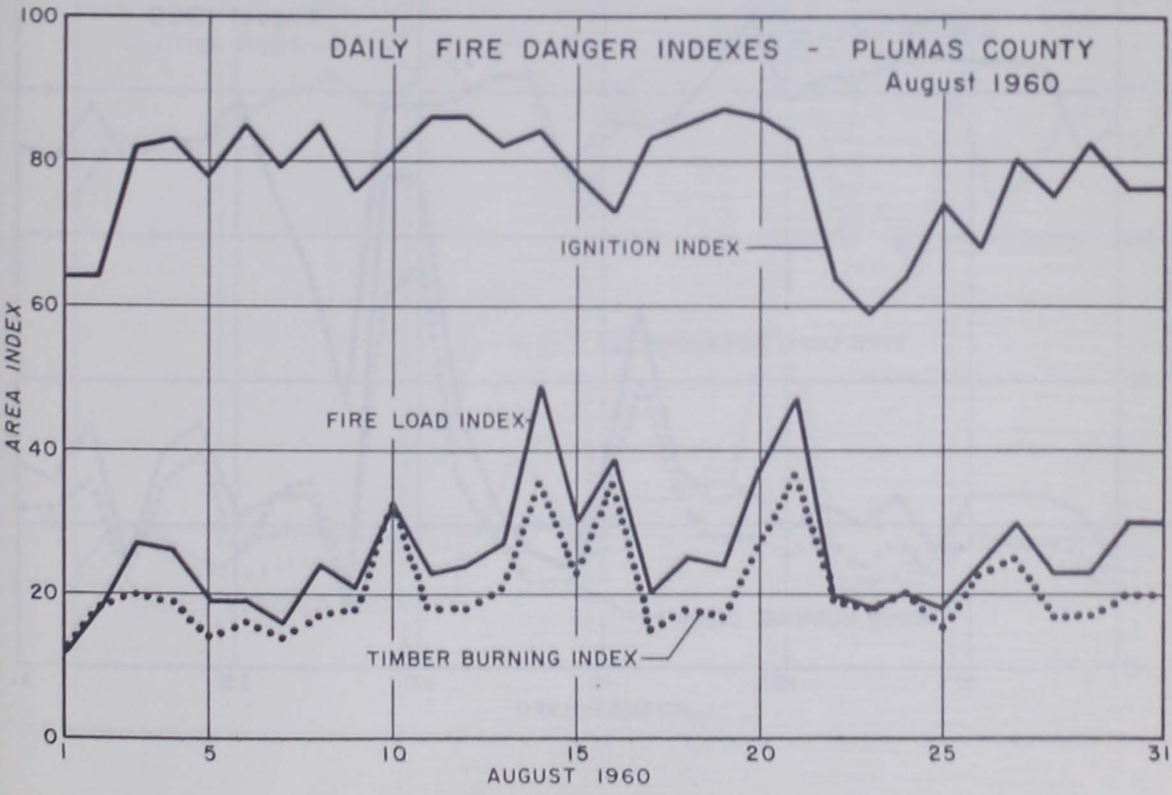
In southern California a hot, dry June started rapid drying of both green and dead fuels. The mid-July heat wave stepped up the process so that fire danger indexes climbed to all time highs for so early in the fire season. During this period the air was quite unstable, and on several days thunderstorms occurred. Under such a combination of weather conditions, fires could be expected to start easily and behave erratically so that control would be difficult.

Fires started--234 of them (almost 4 times the average)--and 230 were held at relatively small acreages. Four of the fires blew up and became major conflagrations. The man-caused Polecat fire, Angeles National Forest, started on July 17, when the ignition index peaked at 91. Under blow-up weather conditions it made major runs on the 18th and 20th. While fire forces were committed to controlling the Polecat fire, lightning storms started additional fires. On July 20, with the burning index in the extreme range, the Johnstone (Angeles National Forest), Magic Mountain (Angeles National Forest), and White Mountain (Los Padres National Forest) fires were started by lightning. Weather-induced blow-up conditions prevailed on July 20 and 21, and resulted in these other three fires also reaching the conflagration stage.



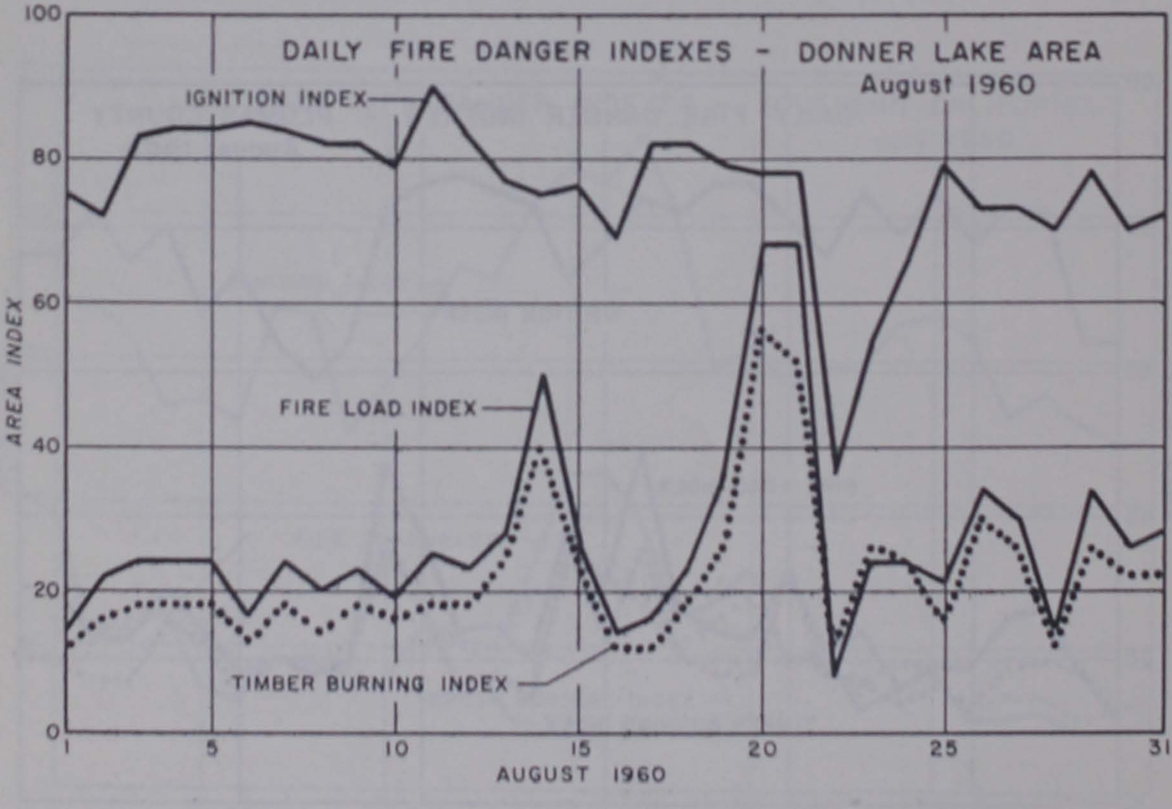
In Plumas County the temperature was 95 to 105 degrees in mid-August compared to a normal of 83. The amount of moisture in fine dead fuels such as grass and leaves was about 2 percent instead of the usual 5 percent. Heavier fuels were drier than average.

As a result the burning index was very high on August 13 and 15, when the Mosquito and Virgilia fires started. On the second day of each fire relative humidity dropped an average of about 6 percent, down to the 10 or 11 percent level. Fine fuel moisture dropped proportionately and thereby raised the burning indexes into extreme. With the ignition index already above 70, fire control was made more difficult by fires spotting across firelines. Cooler weather by August 17 lowered the burning indexes from extreme down to high.



In the Donner Lake area the potential for fire starts and extreme fire behavior was even greater by August 20, when crews were still mopping up the timber fires to the north on the Plumas National Forest. The ignition index of forest fuels was high, having hovered around 80 for several days. High winds and low fuel moistures boosted the burning index to 56, far into the extreme class, indicating fast fire spread and very intense burning conditions.

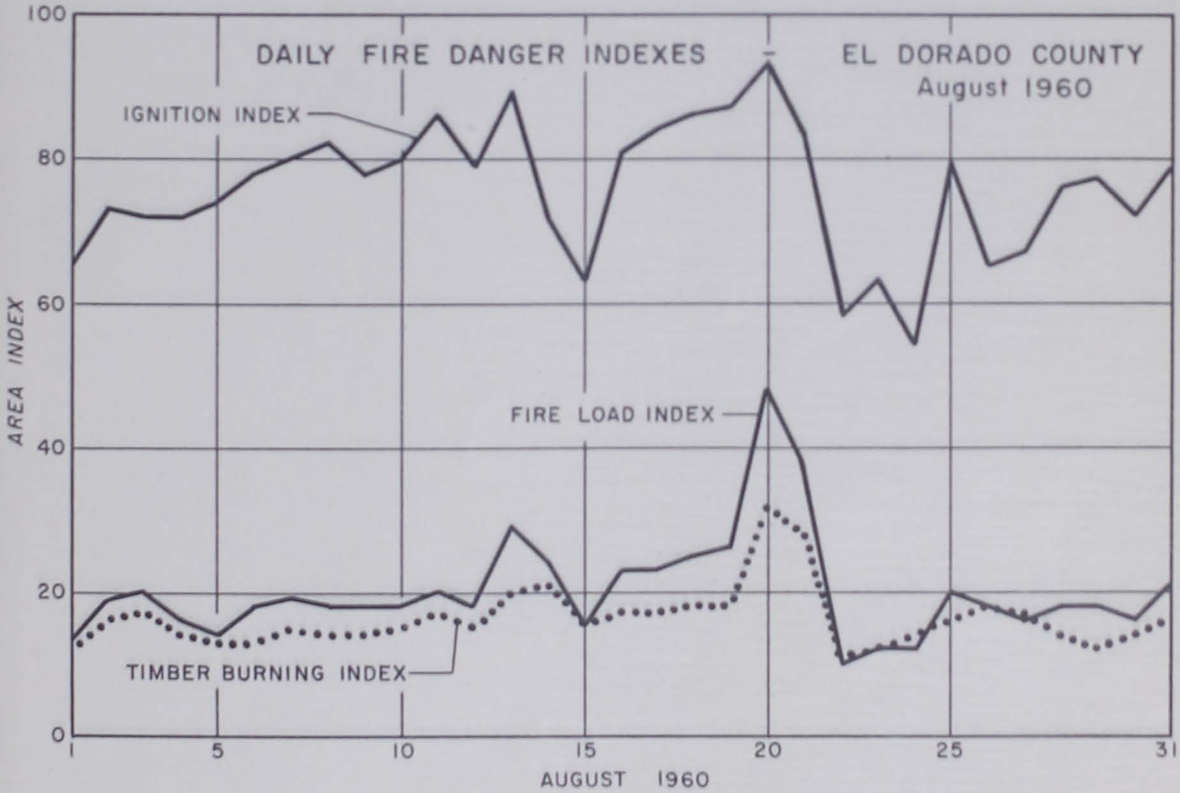
The Donner Ridge fire started August 20. Its behavior was as bad as indicated by the indexes and it ran many miles the next day. A cold front passage on the 21st brought higher humidities and lower temperatures. However, the speed of the winds more than offset the immediate effect of the damper and cooler air. After the colder air mass took full effect--as shown by all indexes dropping to low levels--fire activity slowed noticeably.



August 20 also saw the start of the Volcano (Homestake Mine) fire near Forest Hill, California, on both the Tahoe and Eldorado National Forests. The ignition index had reached 93, indicating a high susceptibility of fuels to ignition because of very low fine fuel moisture, and consequently a high danger of spot fires.

Fire spread by spotting caused the major runs of the Volcano fire on August 20 and 21. Extreme burning indexes of 32 and 28 on the first two days of the fire were also reflected in the fire behavior. Large patches of timber burned intensely as a unit and lifted great quantities of partially burned needles and leaves into the air. Prevailing surface winds carried the ignitors ahead to start concentrations of spot fires, which coalesced into intense unit area fires and were soon joined by the steadily advancing ground fire.

Like the Donner Ridge fire, the Volcano fire moderated appreciably after the cold front passed and cool damp air dominated the area. But on August 25 the ignition index again climbed toward 80, and fine fuels were again sufficiently dry to be easily ignited by flying sparks.



CONCLUSION

1960 appears to be the most severe fire season in recent times, as fire losses testify. So do three basic indexes of the wildland fire danger rating system which were applied to six sample areas in California. The consistently high ignition, burning, and fire load indexes appear to measure accurately the influence of hot dry weather on forest fuels. Very low fine fuel moistures resulted in high ignition indexes, and more than 5,000 fires started through September 30. The high burning indexes are reflected in the behavior of the fires that became large. Many fires plus large acreage losses are also reflected by the seasonal fire weather severity which indicates a fire job load approaching almost twice normal throughout California. These indexes appear to show a great deal of promise for current planning of fire prevention and suppression activities.

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No. 55 January 1961

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SELECTING FIRE CONTROL PLANNING LEVELS BY BURNING INDEX FREQUENCIES

By

Arthur R. Pirsko, Forester
Pacific Southwest Forest and Range Experiment Station
U. S. Forest Service

How do you pick the base level of burning conditions for planning a fire control organization? Hiring and equipping full-time crews to handle the worst possible situation is obviously not economic, for extreme burning conditions occur infrequently. The more realistic practice is to set up a full-time organization adequate for normal or somewhat above normal burning conditions and then fill in with emergency crews when the situation demands. The planner knows the resource values and production goals he must protect. His problem is to decide on a cut-off point for the size of full-time and emergency force he can maintain economically.

Selecting the point between normal and above normal has always been a problem. Planning concepts for fire control organizations have long been tied to normal burning conditions (Dubois 1914, Hornby 1936). Worse-than-average conditions were recognized to exist, but the severity of burning conditions could not be determined until after the fire season. Then, as Show and Kotok (1930) suggested, severity was described by the percentage of fires reaching over 10 acres in size and the total area burned in the most difficult years. Show and Kotok stressed the importance of aiming protection effort at controlling fires under average worst conditions but had no burning index to serve as a yardstick. More recent fire control planning, as in Canada, relates organization plans to average burning indexes (Beall, 1950). The problem in planning, though, is to measure above-average conditions.

One method arbitrarily took the "average worst day" as the planning base for "average bad" conditions. The approach was first to select an "average worst year"--defined as the third worst in the last 10 years as determined by the sum of daily burning indexes. Then for this year the average burning index of the worst 15 percent of the days was computed and taken as the base level.

This paper reports a method of selecting the planning base which tells the planner the probable frequency of a given burning index. It was devised for use with the California fire danger rating system, in which the burning index is rated on a scale of 0 to 100 and expresses the expected fire spread and intensity as influenced by weather. The index, therefore, is a good measure of relative job size--the higher the index, the more men and equipment will be needed to meet a desired fire-control goal in a given period. But a base such as the "average worst day" must not be applied too widely. If it is, it may not allow for geographical variations in climate.

The recent revision of the California fire danger rating system[1] showed that an area the size of a national forest could have as many as seven different climatic regimes. When differences in weather, fuel, and topography were considered, the State as a whole had to be divided into 144 fire danger rating areas. Therefore, it was decided to use these divisions and compute base levels for fire control planning in each area in the California Region of the Forest Service.

The approach chosen was to determine from fire weather records the frequency of occurrence of each burning index. Data used were the daily burning indexes in a 6-year period, for July and August in northern and central California, and for July, August, and September in southern California. Each frequency was expressed as a percent of the total, the percents were cumulated, and the cumulated percents were plotted on arithmetic probability paper.

The resulting charts make it easy to see the frequency of "easy," "normal," or "bad" days. Planning levels can be set to cover a specified percent of the days during a fire season, and the burning index to be expected at this emergency point can be read from the chart. In the California Region, the planning level selected for the fire-control organization is 90 percent frequency; the corresponding burning index is called the "area base burning index."

The variability of planning levels can be illustrated by probability curves for four fire danger rating areas (figs. 1, 2, 3, and 4). In these areas, base indexes range from 12 in the north coast mountains, to 29 in the central coast, and to 17 and 43 in two adjacent southern

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[1] Schroeder, M. J. Development of the California fire danger rating system. Bul. Amer. Meteorol. Soc. 39(3): 178-9. (Abstract; paper presented at Amer. Meteorol. Soc. Session, A.A.AS. Logan, Utah, June 18, 1958.)

California areas. This means that in the central coast area, for example, 90 percent of the days will have a burning index of 29 or lower, and 10 percent of the days will have a burning index above 29.

The charts help the planner visualize weather differences between areas. The average burning index, which can be expected half of the time, is not as much alike in adjacent areas as one might expect. In the two southern California areas, for example, one averages 11 while its neighbor averages 26. The extreme conditions also differ markedly; in one the burning index is 46, in the other 88.

New charts need not be prepared if management is intensified to increase productivity. As the acceptable fire loss becomes less, the frequency level can be increased--say from 90 to 95 percent--and a new area base can be read from the chart.

Thus, cumulative probability curves give the planner flexibility. He can rate each area on its distinctive weather conditions, and he easily can adapt his organization to future changes in the job load. To produce such curves, good fire weather records are needed, and access to machine data processing is desirable. Frequency analysis by hand computation is a laborious, costly task.

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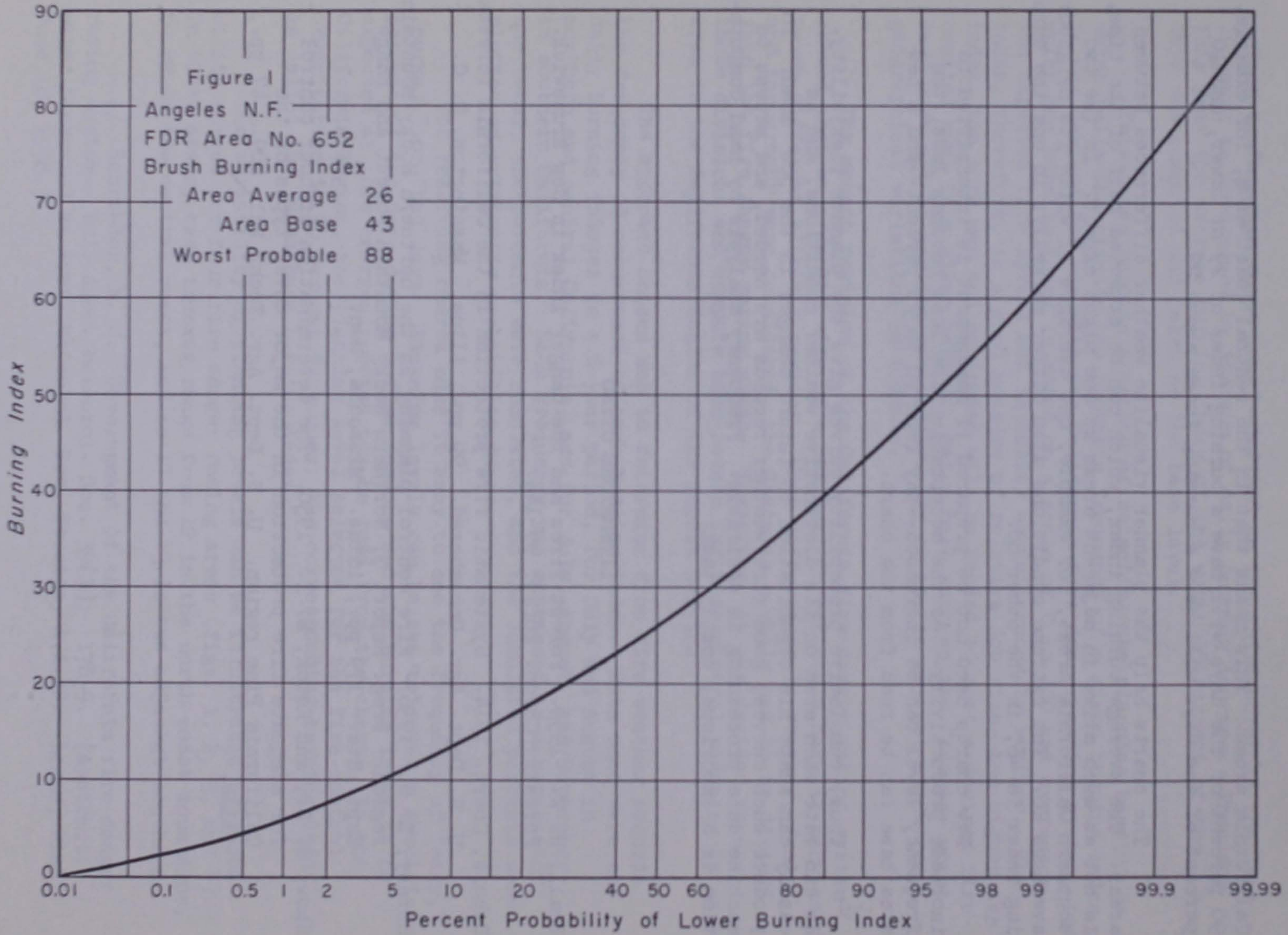

Figure I

Angeles N.F.

FDR Area No. 652

Brush Burning Index

Area Average 26

Area Base 43

Worst Probable 88

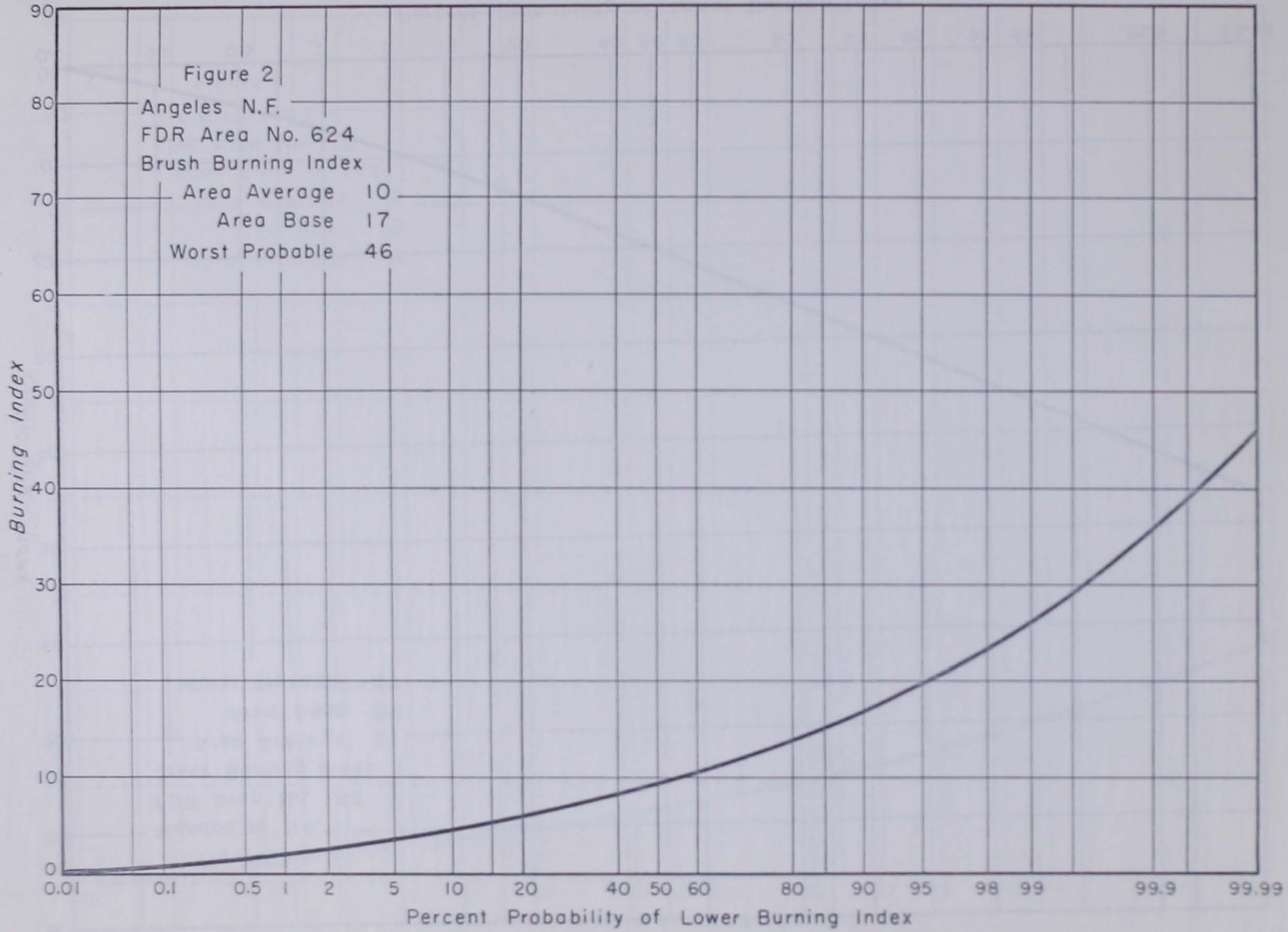

Figure 2

Angeles N.F.
FDR Area No. 624
Brush Burning Index
Area Average 10
Area Base 17
Worst Probable 46

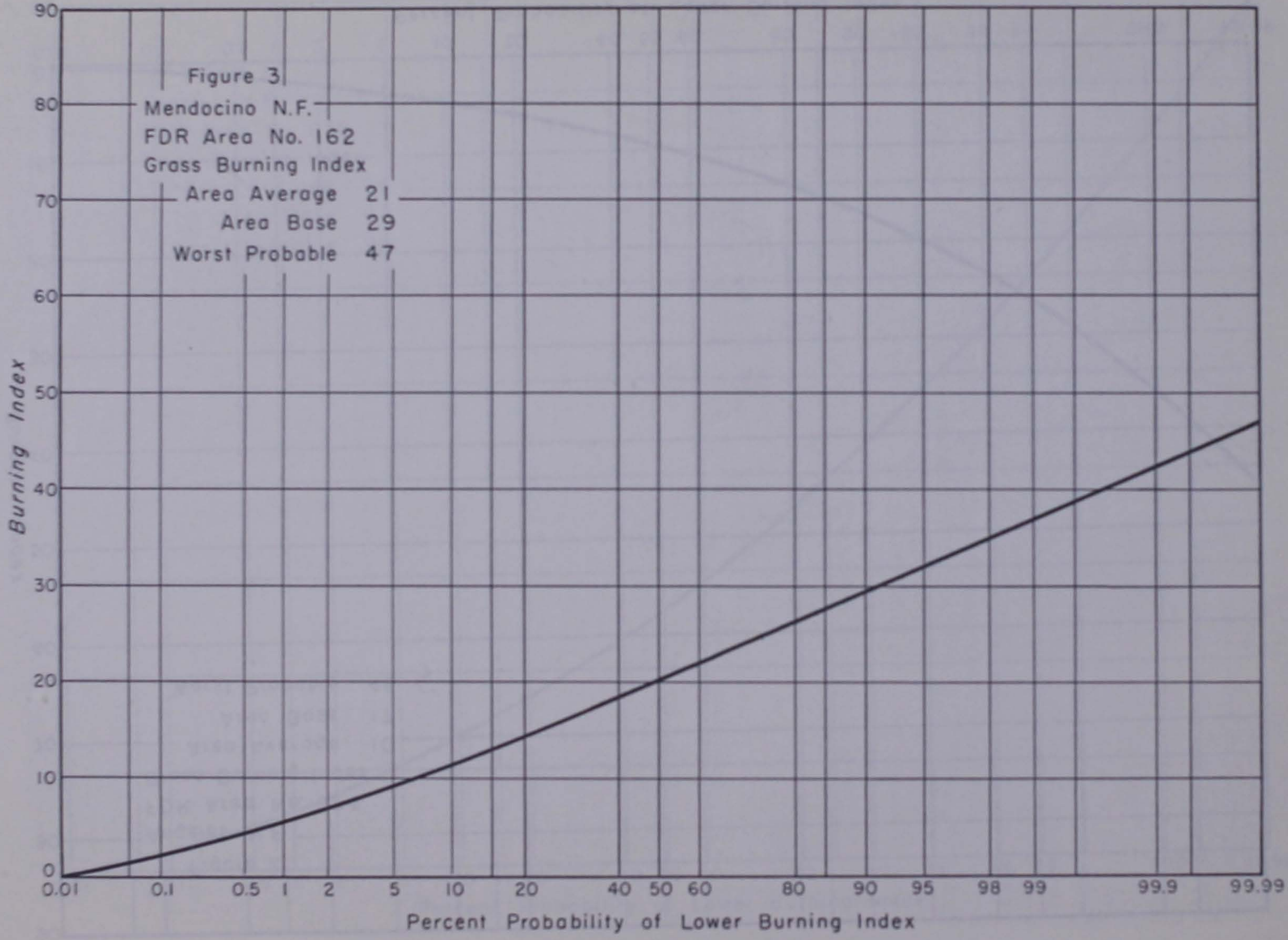

Figure 3

Mendocino N.F.

FDR Area No. 162

Grass Burning Index

Area Average 21

Area Base 29

Worst Probable 47

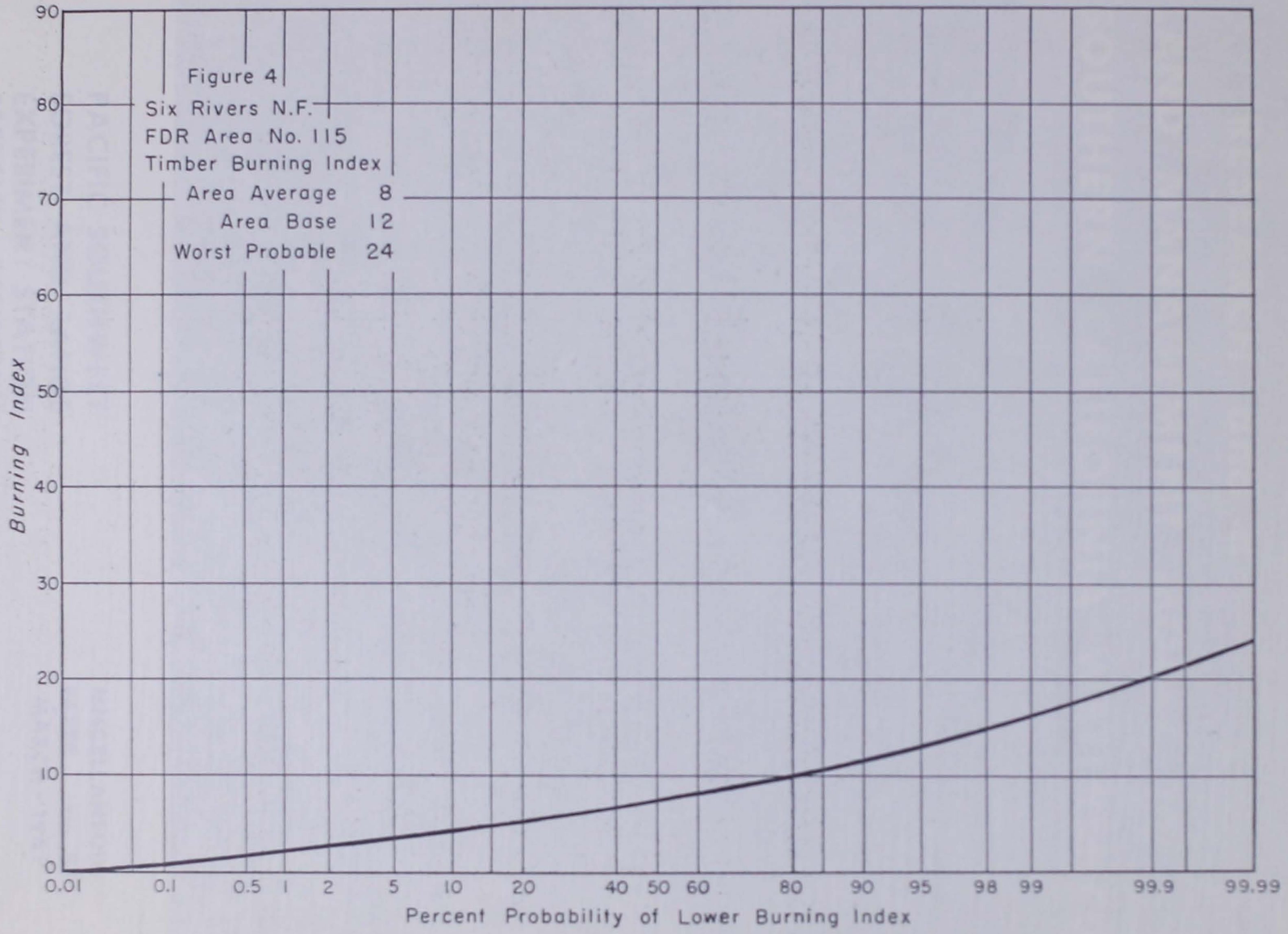

Figure 4

Six Rivers N.F.

FDR Area No. 115

Timber Burning Index

Area Average 8

Area Base 12

Worst Probable 24

RESEARCH and a LAND MANAGEMENT MODEL for SOUTHERN CALIFORNIA WATERSHEDS

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PAPER . . . No. 56
MARCH - 1961

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

Cover photo: The mountains and the city. The San Gabriel Mountains--some of the steepest most unstable mountains in the world--perched above a vast urban area. Research on the San Dimas Experimental Forest is aimed at controlling large brushland conflagrations, reducing floods and erosion, and improving water yield.

RESEARCH AND A LAND MANAGEMENT MODEL
FOR SOUTHERN CALIFORNIA WATERSHEDS

By

Walt Hopkins, Jay Bentley, and Ray Rice

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Miscellaneous Paper 56 March 1961

U.S. Department of Agriculture, Forest Service
Pacific Southwest Forest and Range Experiment Station
Berkeley, California

The Johnstone Fire, about 30 minutes after the lightning strike, July 20, 1960. By nightfall the next day most of the 17,000-acre San Dimas Experimental Forest had been swept by the fire.

RESEARCH AND A LAND MANAGEMENT MODEL FOR SOUTHERN CALIFORNIA WATERSHEDS

By

Walt Hopkins, Jay Bentley, and Ray Rice

A noon-time bolt of lightning on a 107° day, July 20, 1960 is our starting point.

Within one hour fire had wiped out the vegetation on more than 400 acres--by nightfall 3,000 acres more. The end of the next day found more than 12,000 of the 17,000-acre San Dimas Experimental Forest with little remaining but exposed soil and ashes. By the end of the week about 15,000 acres were burned over. None of the experimental watersheds was spared.

In one sense, the fire was a major scientific disaster. Research installations and chaparral vegetation under study since 1932 were gone. But the fire did not make San Dimas a total loss to science. The fire had created a large area of chaparral land in critically unstable condition--a condition that occurs all too often in southern California. Here for the first time, however, fire had swept an area where soils, vegetation, and watersheds have been studied intensively for more than a quarter-century. Thanks to prompt action and a great deal of help, we have been able to turn the situation to advantage.

Before the fire was under control, improvised stream-gaging stations and raingages were "jury rigged" and back in operation, and emergency research planning was started. Plans were drawn to re-establish field installations and to evaluate broadscale land treatment measures aimed at stabilizing and managing fire-denuded watersheds. This is a unique opportunity to capitalize on past knowledge. For the first time we are able to measure quantitatively the results of restoration, protection, and management efforts on chaparral land.

Through the combined efforts of several agencies, the job of establishment is nearly finished. The San Dimas Experimental Forest is rapidly becoming the most intensively studied and managed block of wildland in the country. Congress provided a supplemental appropriation. The engineering staff of the Angeles National Forest has handled much of the rehabilitation planning and supervision. Labor crews provided by the California Division of Forestry and the Los Angeles County Fire Department have been working side by side with Forest Service crews for months. The State Department of Water Resources and the Los Angeles County Flood Control District have provided engineering survey teams and engineering planning and design for streamflow- and sediment-measuring structures. As a consequence, the San Dimas Experimental Forest is well embarked on a 5-pronged research program:

1. Emergency sowing of burned-over watersheds
2. Erosion control
3. Conflagration control
4. Improvement of water yield
5. Development of a large pilot model for the management of chaparral lands.

EMERGENCY SOWING OF BURNED-OVER WATERSHEDS

Emergency sowing of herbaceous plants soon after a fire is an accepted practice in southern California watersheds. The purpose of this first aid treatment is to establish a temporary cover for protection of the watershed while the brush is slowly recovering.

Although reasons for sowing denuded watersheds are obvious, the effects of sowing have never been quantitatively measured. Does the added cover pay in terms of reduced sediment in the stream channels? Are more expensive and more effective revegetation measures justified? The burned watersheds of the experimental forest should answer these questions.

Annual species are usually sown because annuals are hardy and reseed themselves each year. The seed is abundant and cheap. For years black mustard was the most commonly sown species. In the last 6 years it has been largely replaced by common ryegrass in southern California, but on San Gabriel watersheds the two species have been sown in mixtures. Two other annuals--Wimmera ryegrass and Blando brome--are now being used in some sowings. Which of the annuals provides the best cover on different sites? This is another question being studied.

Deep-rooted perennial grasses also have been suggested for emergency temporary cover. They are commonly sown where permanent cover is desired, but perennials have never been widely tested on burned-over southern California watersheds. They are now being compared with annuals in the experimental watersheds to see if they provide better cover, especially at upper elevations too cold for good growth of annuals. The comparisons include tests of individual species and mixtures of species as both emergency and permanent cover.

From October 23 to November 29, a total of 13,496 acres were sown by helicopter within and adjacent to the experimental forest. An additional 83 acres were sown by hand, and 29 acres were sown with a heavy duty rangeland drill.

"First aid" in action--loading a helicopter for emergency watershed revegetation. Except for control areas designated for no artificial seeding, the entire experimental forest was sown to selected annual or perennial grasses in the fall of 1960.

Helicopter costs for sowing large areas with 10 pounds of seed per acre, were about $1.00 per acre. For small watersheds and plots, the cost of aerial application was about doubled. Seed cost about 60 cents an acre for common ryegrass and mustard, and $2.00 to $7.00 for the perennial grass mixtures.

EROSION CONTROL

Southern Californians know all too well the consequences when heavy rainstorms hit fire-denuded watersheds. The San Dimas Experimental Forest has furnished some of the evidence. For example, in 1953 the upper 500 acres of 1,500-acre Wolfskill Canyon were burned. The first storm after the fire was not too uncommon--the kind you can expect every 3 or 4 years. It produced a flood peak 68 times the normal, and erosion was increased 30 times.

Another example has been recorded in Bell Watershed No. 2 since the 1960 fire. Over the past 27 years annual erosion rates have averaged about 1,800 cubic yards per square mile.

Building contour terraces. In addition to revegetation, physical measures aimed at retarding runoff and erosion are being tested in experimental watersheds.

The first storm after this fire, on October 9, 1960, wasn't much of a storm--0.94 inch in 19 hours. Yet the erosion rate was more than 3,000 cubic yards: 1.7 times the annual rate from just one small storm.

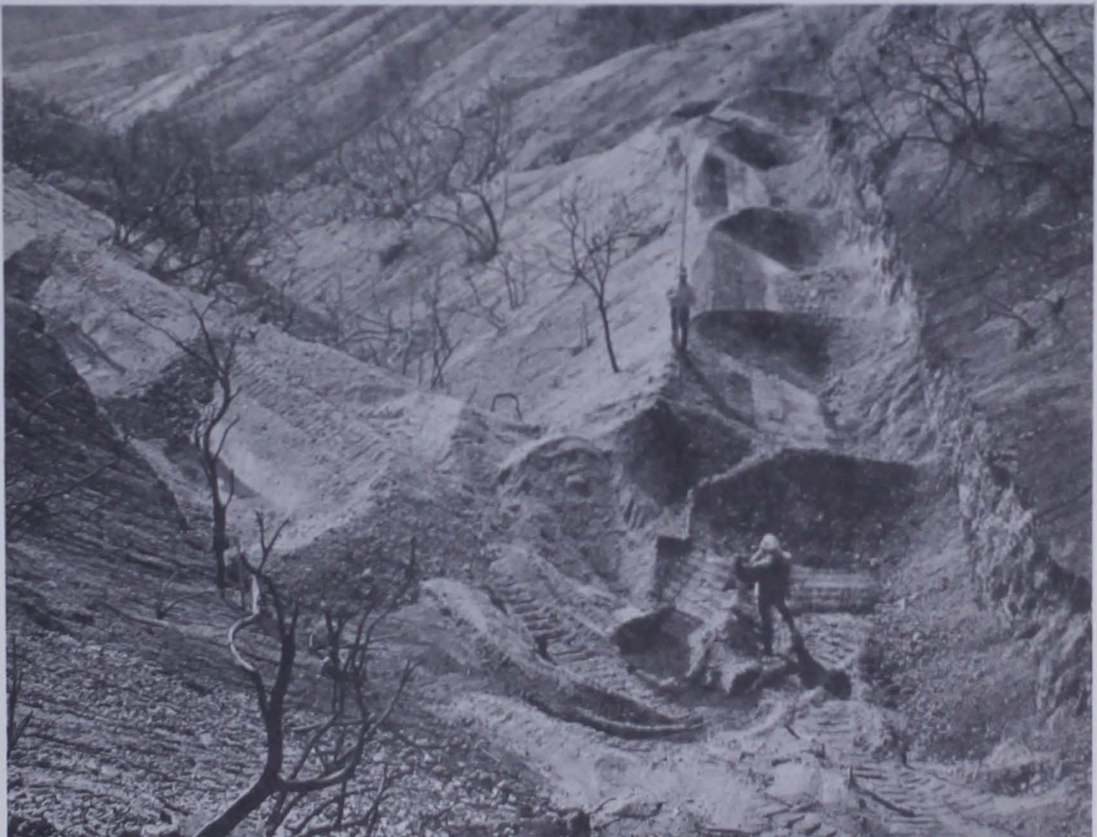
In fact, it doesn't have to rain for erosion to be a problem. A study in the Arroyo Seco, a few miles west of the experimental forest, revealed that (1) dry creep erosion in the steep unstable San Gabriel Mountains can exceed water-borne erosion, and (2) post-fire dry season erosion was 2 to 35 times the preburn rate.

Now we are embarked on intensive tests comparing nearly 30 alternatives aimed at reducing post-fire soil erosion. If erosion rates could be reduced even a small amount, the savings would be sizable.

Small Watershed Tests

Twenty-five small watersheds varying in size from 2 to 8 acres have been established near the Tanbark field headquarters. Each has a flow measurement flume and debris basin, and except for an untreated control watershed to be used as a basis for comparison, each has one of, or combinations of, the following physical or vegetative treatments:

1. Contour basin-terraces. --Large permanent terraces were constructed in 9 of the watersheds. This practice was developed in the Intermountain Region of the Forest Service. The terraces were constructed with a heavy bulldozer and were spaced on contour 40 to 90 feet apart depending on slope. A completed terracing system provides dead storage for a storm that produces about 3 inches of rain. The system will also store about 550 cubic yards of sediment per acre.



Completed terrace. The listed basins hold runoff and lessen the lateral movement of water within the terrace.

Side slope stabilization. Barley planted in furrows on close contours.

2. Side slope stabilization.--To impede overland flow of water and sediment on side slopes in 9 of the small experimental watersheds, barley seed and fertilizer were placed in furrows to form dense rows on 2-foot contour intervals. Barley was chosen because it grows more vigorously than most species during cool winter weather. The fertilizer was included to promote earlier and heavier growth.

3. Stream channel checks.--Small dams were constructed of cement combined with soil and rock available at the dam sites in 9 of the watersheds. Purpose of these dams is to prevent channel downcutting, to stabilize side slope soils, and to spread out streamflow, thereby reducing its velocity and erosive power.

4. Broadcast sowing of perennial grasses.--A mixture of perennial grasses with a small amount of annuals was sown at a rate of 20 pounds per acre in 4 watersheds, and at 4-1/4 pounds in 4 others. Hardinggrass and pubescent wheatgrass were the dominant deep-rooted perennials.

5. Broadcast sowing of annual grasses.--Nine other watersheds were sown with annual grasses--5 at 20 pounds per acre and 4 at 2-1/2 pounds. The mixture was composed of 4 parts Wimmera ryegrass and 1 part Blando brome.

Constructing channel checks. Soil cement channel checks to reduce downcutting, stabilize side slopes, and spread streamflow are under test in nine experimental watersheds.

Constructing watershed flume to measure storm flows and suspended sediment. Note debris basin and spillway downstream and in background.

The use of soil binder chemicals was also explored. We had hoped to find a chemical to stabilize the soil during the early part of the rainy season before an effective plant cover can be established. Twelve chemicals were studied in the laboratory, and three of these were tested in large field plots under artificial rainfall. The trials did not uncover a chemical sufficiently promising for application in the small watersheds. Despite this disappointment, it is recognized that erosion control during the critical period immediately after a fire is a serious problem, and ways must be found to protect the soil prior to vegetation establishment. Further chemical tests will be made.

Mustard-Ryegrass Watersheds

Eleven other watersheds varying in size from 9 to 87 acres, each with a flume to measure flows and suspended sediment, are dedicated to a comparison of ryegrass vs. mustard as an emergency vegetative cover. This is the first time it has been possible to make a quantitative comparison of these alternatives.

Lysimeter Tests

The burned-over lysimeters are again at work. The new study seeks to answer the question "How do infiltration rates vary under a mustard or ryegrass cover?" If one plant encourages more infiltration and percolation than the other, runoff would be less, and presumably erosion rates would also be less.

CONFLAGRATION CONTROL

An obvious first step in reducing erosion and flood damage is to prevent widescale destruction of the vegetation by disastrous fires. For this reason, fire control effort in southern California brushfields is more intensive than on any other kind of wildland. Firefighting forces are highly organized and equipped for fast, hard hitting ground and aerial attack. Aggressive action controls some 98 percent of the fires while still small. Yet, despite many recent improvements in firefighting, large acreages are burned each year.

The few fires which escape early control, usually under extreme weather conditions, build up into conflagrations. Where terrain is so excessively steep and the heavy fuels are tinder dry, such fires cannot be readily stopped in the continuous cover of dense brush. By the time expensive, back-breaking effort, aided by favorable weather, has confined the fire, thousands of acres have burned.

A new approach that is rapidly gaining momentum, is to modify the fuel conditions by breaking the expanses of brush into smaller units for more effective fire control. This is done by converting the heavy brush to a cover of light-volume fuel, such as grass, at strategic intervals on wide strips or blocks of land. These are called fuel-breaks. The breaks provide access for safer firefighting where modern techniques can be more effective.

Firefighting agencies in southern California started several years ago by building wide breaks instead of the old narrow ones. In 1957, they organized a research and action program aimed at improving the techniques for building breaks and at expanding use of this new approach to fire control. Numerous fuel-break demonstrations have been started and more are planned.

Now, the experimental forest provides an area where an intensive fuel-break system can be developed as a model of the future for San Gabriel watersheds. This system has been planned, and chemical control of brush regrowth will start this year on 2,000 acres. About 1,000 more will be added within the next two years.

Studies to sharpen the techniques of brush conversion on this kind of land have also been started. The sites have been classified and mapped. Adaptation of different plant species as permanent cover is being tested, and methods for their establishment on different sites are being developed. Included are plants which have been reported to be fire retardant or slow burning. Techniques of aerial spraying and hand spraying to eliminate brush will be tested extensively.

IMPROVEMENT OF WATER YIELD

Research at San Dimas aimed at the improvement of water yield starts with the fundamental question upon which the experimental forest was founded--what happens to rainfall when it reaches the watershed? Over the years it was found that during an average year of 27 inches of rainfall, evapotranspiration losses were 15 inches--indicating considerable opportunity for water savings. The lysimeters and then plot studies showed that only under a grass cover, and then only on deep soils, was there opportunity for increased groundwater yield.

Drawing on these results, in 1958 we placed two watersheds under intensive management. In Monroe Canyon we started to see how much more water can be yielded by removal of riparian and associated streambottom vegetation. In Bell Watershed No. 2, we asked "How much more water can be yielded by deadening side-slope chaparral growing on deep soils?" Two valuable years of records were obtained before the fire.

Monroe Canyon Study

The performance of Monroe Canyon and that of adjoining Volfe Canyon, each with a long-established chaparral cover, had been measured for more than 20 years. In the spring of 1958 and in the spring of 1959, a total of 38 acres of riparian and associated streambottom trees were removed from Monroe Canyon. This was followed by herbicide spraying of brush and stump sprouts.

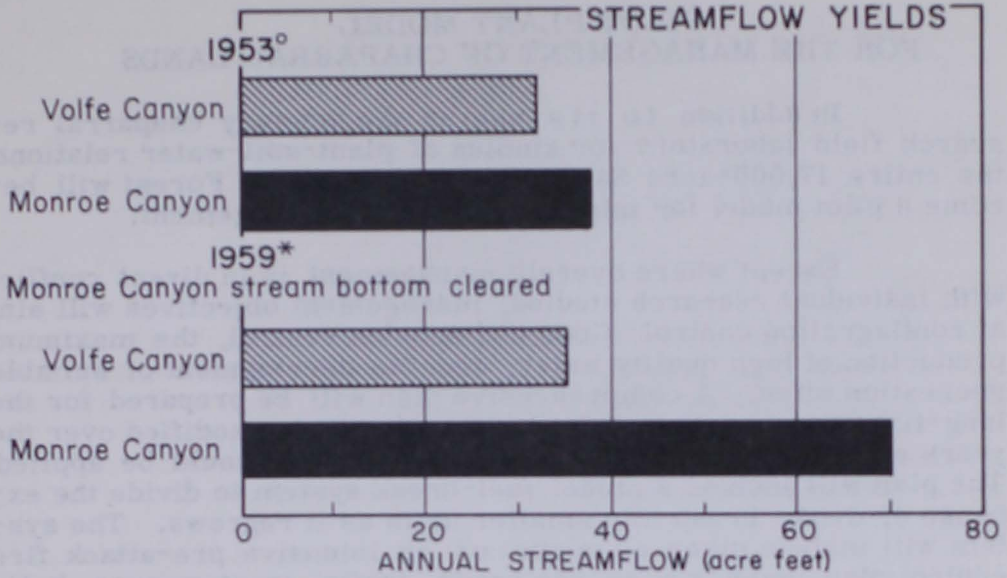
Both 1958-59 and 1959-60 were "dry": rainfall was about half the average. Despite this, during the 12-month period, June 1, 1958 through May 31, 1959, streamflow in Monroe Canyon was 30 acre-feet more than would have been expected if the streambottom had not been cleared--about an acre-foot of water for each cleared acre.

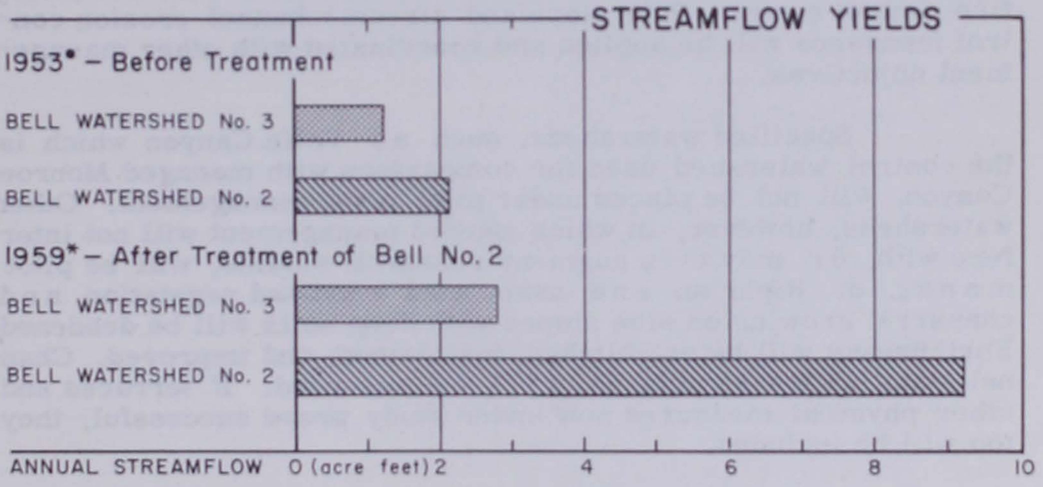
This major study aimed at management for increased water yield continues as part of the post-fire research program. A soil survey was made. The deep soils in Monroe Canyon are located. The canyon has been seeded with a mixture of Wimmera ryegrass and Blando brome. The deep soil areas and the canyon bottom will be sprayed with a herbicide as often as necessary to maintain a grass cover. Volfe Canyon, on the other hand, was not and will not be seeded. It will continue as an unmanaged control for comparison with Monroe Canyon.

Bell Watershed Number 2

Forty acres of chaparral in 100-acre Bell Watershed No. 2 were sprayed with a mixture of 2, 4-D and 2, 4, 5-T in the spring of 1958, then again in 1959 and 1960. Adjoining Bell No. 3 was left unsprayed as a control. When comparable periods of current and antecedent rainfall are compared, we find that streamflow in treated Bell Watershed No. 2 was about 5 1/2 acre-feet greater than would have been expected without treatment; this amounts to an annual increase of about 1/10 of an acre-foot per acre treated.

In the post-fire research program, management of Bell Watershed No. 2 is similar to that of Monroe Canyon. The watershed has been seeded to Wimmera ryegrass and Blando brome. Vegetation on deep soils and in the riparian zone will be sprayed with herbicides as often as necessary. Meanwhile, its performance will be compared with that of (a) Bell Watershed No. 3, which has been seeded to domestic ryegrass; (b) Bell Watershed No. 4, which has not been seeded at all; (c) Bell No. 1, which has been seeded to perennial grasses.





° June 1, 1952 through May 31, 1953
(Rainfall: Current year 15.9 inches,
antecedent year 40.5 inches)

* June 1, 1958 through May 31, 1959
(Rainfall: Current year 14.9 inches,
antecedent year 47.3 inches

(Above) Effect of removing canyon bottom trees and brush. Streamflow from managed Monroe Canyon and unmanaged Volfe Canyon for comparable periods before and after 38 acres of stream channel vegetation was removed from Monroe Canyon.

(Below) Streamflow from managed Bell Watershed No. 2 and unmanaged No. 3 for comparable periods before and after 40 acres of brush were deadened by herbicides on side slopes with deep soils in 100-acre No. 2.

PILOT PLANT MODEL
FOR THE MANAGEMENT OF CHAPARRAL LANDS

In addition to its use as the primary chaparral research field laboratory for studies of plant-soil-water relations, the entire 17,000-acre San Dimas Experimental Forest will become a pilot model for intensive chaparral management.

Except where overall management is in direct conflict with individual research studies, management objectives will aim at conflagration control, flood and erosion control, the maximum production of high quality water, and the development of suitable recreation sites. A comprehensive plan will be prepared for the long-time management of the forest. It will be modified over the years as research shows new practices which should be applied. The plan will include a model fuel-break system to divide the expanse of dense brush into smaller units as it regrows. The system will include other elements of an intensive pre-attack fire control plan, such as access roads, trails, tractor-ways, helispots, water tanks, pump and hose installations, and the necessary fire control crews. Side-slope and stream-channel erosion control measures will be applied and coordinated with other management objectives.

Specified watersheds, such as Volfe Canyon which is the control watershed used for comparison with managed Monroe Canyon, will not be placed under pilot plant management. Other watersheds, however, in which applied management will not interfere with, or may even augment research studies, will be pilot managed. Riparian and associated woodland vegetation and chaparral growing on side slopes with deep soils will be deadened. Fuel-breaks will be established, maintained, and improved. Channel stabilization structures will be installed. If terraces and other physical measures now under study prove successful, they too will be included.

A prescription will be written for each watershed. Then--within the scope of available manpower, equipment, and materials--erosion control measures and steps to improve water yield will be applied. The most critical areas, or those with the most promise of improvement will be tackled first, and in due course, improving as we go, the entire tract will be under intensive management--a multiple use model to guide the management of some of the most important wildland watersheds in the country.

Firefighting Chemicals
. . . NEW WEAPONS FOR THE FIRE SUPPRESSION CREW

James B. Davis
Dean L. Dibble
Clinton B. Phillips

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FIREFIGHTING CHEMICALS--NEW WEAPONS FOR THE FIRE SUPPRESSION CREW

By
James B. Davis and Dean L. Dibble
Pacific Southwest Forest and Range Experiment Station

and
Clinton B. Phillips
California Division of Forestry

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Appendix--Summary of Ground Tanker Use--1960- 20

Miscellaneous Paper 57 April 1961
U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
Pacific Southwest Forest and Range Experiment Station

FIREFIGHTING CHEMICALS--NEW WEAPONS FOR THE FIRE SUPPRESSION CREW

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"We felt like witch doctors," was the complaint made by a foreman whose tanker crew had been selected to test the fire fighting qualities of "viscous water" (water containing a thickening agent). A few months later the same foreman, thoroughly familiar with the material, was convinced that under many conditions viscous water was superior to plain water in controlling forest fires. This change of opinion was the result of a three-part cooperative study conducted during the summer and fall of 1960 in California and Nevada.

Use of chemical additives for water in forest fire control is not a new idea. The U. S. Forest Service began testing such materials for fire suppression in 1931, and studies in the United States have been conducted periodically ever since (Barrett, 1931; Truax, 1939). Yet use of chemical additives on fires has been limited until recently, for several reasons: difficulty of handling with conventional pumping equipment, cost of the chemicals, logistics, and the fact that some fire fighters were looking for a panacea. Recently, higher values of forest resources and the demand to reduce fire losses have forced foresters to take a new look at chemicals.

Experiments during Operation Firestop in 1954 showed that sodium calcium borate was the best fire fighting chemical tested at that time (Operation Firestop 1954). Operational tests in 1955 were aimed at applying borate slurry from firetrucks because firefighters believed that application to forest fuels would be more accurate and efficient in this manner. Borate proved to be quite abrasive to the types of pumps commonly used in firetrucks, and ground application was abandoned (Miller and Wilson, 1957). Then the air tanker program was launched. Air tankers now drop millions of gallons of chemicals on forest fires annually.

New interest in chemicals that might have ground application was stimulated when the Syracuse University Research Institute demonstrated that viscous water was about 4 times more effective than plain water in extinguishing certain laboratory fires (Aidun, 1960). At Syracuse, laboratory tests with small crib fires showed that when suppressed with water, all five cribs being tested rekindled at least once and some as many as four times. When extinguished with viscous water, 7 out of 9 cribs did not rekindle, and the remaining 2 rekindled only once.

Also, improvements and changes in pumps and mixing equipment solved many problems of handling chemicals.

Fire fighting agencies in California and Nevada 1/ decided in 1960 to pool their resources and conduct a series of observational tests with new materials in ground equipment. Here is what we found:

---Viscous water was more effective than plain water for controlling fires in most forest fuels and in keeping them from rekindling.

---A thick gel made with algin (derived from seaweed) and calcium chloride was even more effective than ordinary viscous water under some conditions.

---Foaming bentonite was superior to plain water for fires burning in heavy fuels but permitted fire to creep through matted grass and leaves.

---Diammonium phosphate solution thickened with a viscosity agent can make some forest fuels almost fireproof for a long period of time.

1/ Agencies cooperating in the experiments included the U. S. Forest Service--Region 5, the Nevada Division of Forestry, the Los Angeles County Fire Department and the California Division of Forestry. The Pacific Southwest Forest and Range Experiment Station of the Forest Service coordinated the project and conducted the laboratory fire tests. Several private chemical companies also cooperated in the study to a large degree.

FIELD TESTS

CHEMICALS TESTED

The following materials were tested for their ability to suppress fires and to retard the spread of fires:

Bentonite foam.--Volclay bentonite No. 200, American Colloid Company plus Dowfax 2A1 solution, Dow Chemical Company: 0.6 pounds bentonite per gallon of water and 4.0 pounds Dowfax per 100 gallons of water. Foamed volume seven times original volume.

Viscous water.--Water containing one of three kinds of thickening agent: (a) Sodium carboxymethylcellulose, 2WXH, DuPont--0.5 percent solution in water (called CMC); ET-460-4, Dow Chemical Company--0.5 percent solution in water (called ET-460-4); (c) Sodium alginate, either Keltex KNF, Kelco Company--0.8 percent solution in water--or Keltex FF--0.4 percent solution in water--same viscosity obtained with each algin.

Calcium alginate gel.--Sodium alginate (Keltex KNF), Kelco Company--0.8 percent solution in water (or 0.4 percent solution of Keltex FF)--plus calcium chloride (37 percent solution) at ratio of 1 part calcium chloride to about 300 parts of sodium alginate solution (called algin gel).

Chemical fire retardants.--Three different solutions of diammonium phosphate, (a) diammonium phosphate, Monsanto Chemical Company--12 percent solution--plus sodium CMC 2WXH, DuPont--0.5 percent solution in water (called CMC-DAP); (b) diammonium phosphate, Monsanto Chemical Company--12 percent solution in water, plus sodium alginate, Keltex FF, Kelco Company--0.6 percent solution in water (called algin--DAP); (c) diammonium phosphate, Shell Chemical Company--18 percent solution in water (called DAP).

TEST PROCEDURES

The field tests were conducted at four separate locations throughout the summer and early fall of 1960. Ignition techniques, methods of application, and flow rates were controlled as carefully as possible under the field conditions in an effort to make the tests uniform.

The earliest tests were held near Mariposa, California. For suppression tests, fires in cribs of railroad ties were sprayed with bentonite foam, CMC, ET-460-4, DAP, and CMC-DAP (fig. 1). Several other cribs were extinguished with water and plain bentonite slurry. Extinguishment time and radiation output were recorded for each fire. For tests of retardant effectiveness, the test liquid was sprayed on one end of a large pile of dry brush (fig. 2) and allowed half an hour or more to dry. The unsprayed end of the pile was ignited, and the fires were allowed to burn into the portion sprayed with retardant.

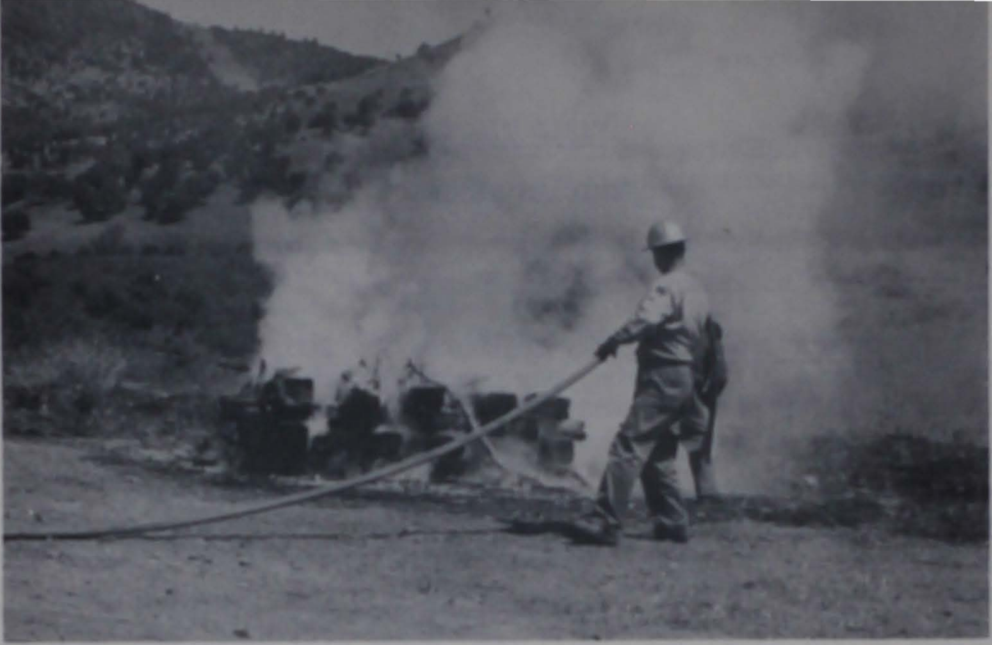

Figure 1.--Extinguishing a railroad tie crib fire with viscous water at a series of field tests held at Mariposa.

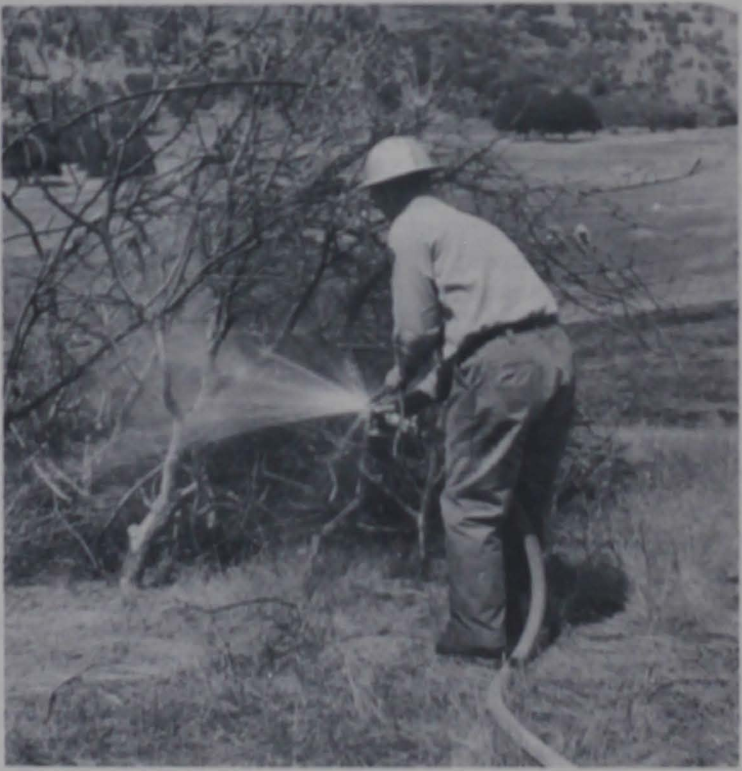

Figure 2.--Spraying viscous diammonium phosphate on end of a brush pile at the Mariposa field tests.

Another series of retardant tests, made in grass plots near Cathay, compared bentonite foam, CMC, and plain water. 2/ A strip along one end of each grass plot was treated with one of the chemicals. The treated strips then dried for 1, 2, or 3 hours. After drying the designated time, plots were ignited at the untreated end, and the fires were allowed to burn into the strips (fig. 3).

Grass plots near Flinn Springs were also used to test the retarding characteristics of algin-thickened water, algin gel, and algin-DAP. Procedures were the same as those used at Cathay.

Similar procedures were also used to test algin, algin gel, and algin-DAP in brush plots near Ramona (Phillips, 1961). The brush was buckwheat and sage; it stood about 4 to 5 feet high and produced very hot fires. Again, treated strips of the plots were allowed to dry 1, 2, and 3 hours before burning.

TEST RESULTS

The data from these tests were not suitable for statistical analysis. At the Mariposa tests, however, records of extinguishment time and radiation reduction indicate that there was a difference in suppressant effectiveness that appeared to be directly related to viscosity (fig. 4). The rate of rekindling was not measured but observers noticed that rekindling was slower and less frequent with viscous water, bentonite slurry, and bentonite foam than with plain water.

CMC-DAP and bentonite foam were the outstanding materials tested for retardant properties on the brush pile fires at Mariposa (table 1). The CMC-DAP completely stopped a test fire, and the unburned portion of the pile could not be ignited with a pneumatic flame thrower after several additional hours of drying. Bentonite foam that had dried 2-1/4 hours effectively stopped the spread of fire burning against the wind. However, unlike the brush treated with CMC-DAP, the treated portion of this pile could be ignited the next day.

In the Cathay grass plots, strips treated with CMC, bentonite foam, and water were all successful in stopping the fire after they had dried for 1 hour. After 2 hours of drying, however, none of these materials stopped the fire, and no significant retarding effect was observed.

2/ Phillips, C. B. Testing CMC as a fire retardant. State of California Dept. of Nat. Res., Div. of Forestry, Fire Control Experiments No. 2. Manuscript 1961.

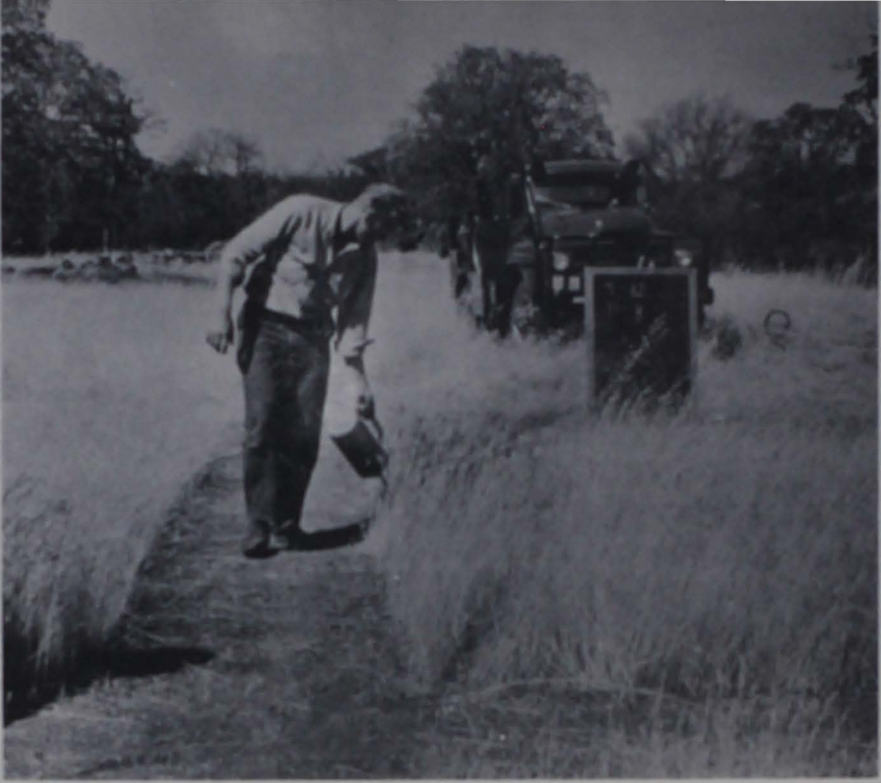

Figure 3.--Igniting a grass plot to evaluate the retardant characteristics of viscous water.

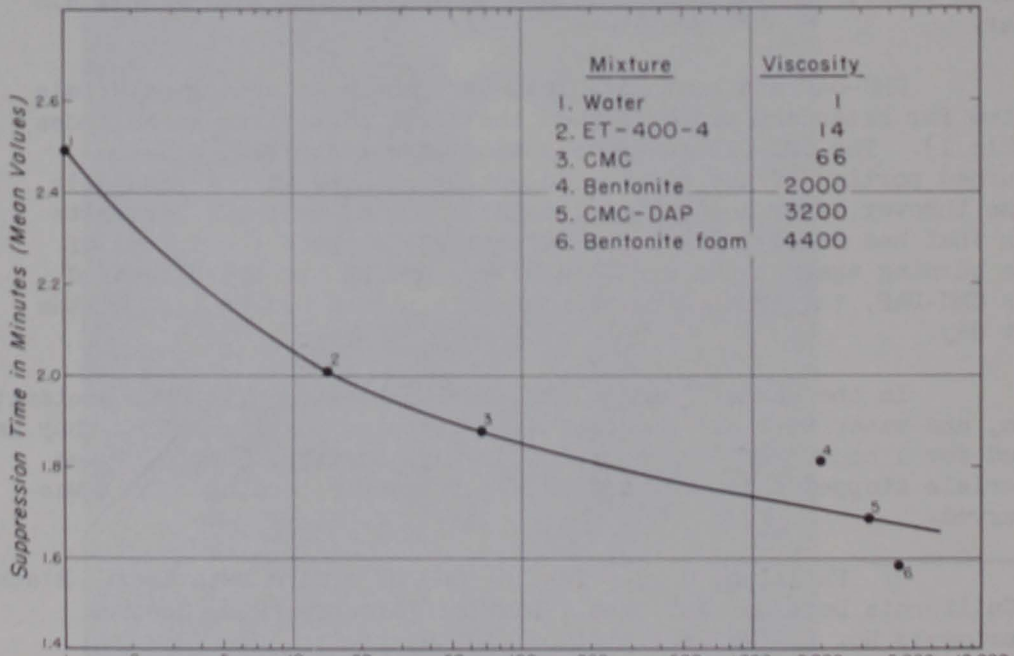

Figure 4.--Average time required to suppress crib fires by various materials tested at Mariposa.

Table 1.--Retardant effectiveness on brush piles

Test material	Fire burning with the wind			Fire burning against the wind		
	Fire stopped	Fire slowed	Fire not effected	Fire stopped	Fire slowed	Fire not effected
CMC[1]	--	--	--	--	x	--
CMC-DAP[1]	--	--	--	x	--	--
ET-460-4[1]	--	--	--	--	x	--
DAP	--	--	x	x	--	--
Bentonite slurry	--	x	--	x	--	--
Bentonite foam[1]	--	--	--	x	--	--
Water (control)	--	--	x	--	x	--

[1] Not tested in fires burning with the wind.

Algin, algin gel, and algin-DAP proved to be effective fire retardants at the Flinn Springs grass plots. Control strips treated with water failed to top fire spread at the end of 1 hour of drying and had no significant retarding effect. On the other hand, strips treated with algin stopped fire completely after 1 hour of drying, and slowed the fire at the end of 2 hours. Algin gel of a low viscosity stopped fire spread after 2 hours of drying, and a high viscosity algin gel after 3 hours of drying. Strips treated with algin-DAP stopped fires after 2 hours of drying. No tests of longer drying time were made with algin-DAP.

These same materials were also successful in the Ramona brush plot tests. Strips treated with algin stopped fires after 1 and 2 hours of drying but not after 3 hours. Algin gel with a medium viscosity stopped fires after 1 and 2 hours and slowed a fire after 3 hours of drying. A high viscosity algin gel completely stopped a fire after 3 hours of drying. Algin-DAP was tested in only one plot after it had dried for 2-1/3 hours and was wholly successful in stopping fire spread.

Algin gel was not developed for field testing until near the end of the fire season. It showed up well in field tests in grass and brush plots and in other tests, but somewhat crude application equipment prevented its being used operationally. Better equipment has been developed to permit further tests of the gel during the 1961 fire season.

OPERATIONAL TESTING

After the Mariposa tests, viscous water, bentonite foam, and algin-DAP were tried on an operational basis by four fire control agencies in California and Nevada during the 1960 fire season.

Nine forest-fire crews, picked for their interest in the study and the normally high fire occurrence in their areas, were assigned to the operational testing program. Each crew was supplied with an injector mixer loaned for test purposes by the Western Fire Equipment Company. Most mixers were mounted on the truck and piped into its plumbing system (figs. 5 and 6).

MATERIALS TESTED

The following materials, in most cases donated by the respective chemical companies, were tested under operational conditions:

Bentonite foam--Wyoming grade, 200 mesh, swelling bentonite clay plus Dowfax 2A1 solution, Dow Chemical Company--0.5 pounds bentonite per gallon of water and 4.0 pounds Dowfax per 100 gallons of water. Tested by two California Division of Forestry crews--Mariposa Forest Fire Station (Mariposa

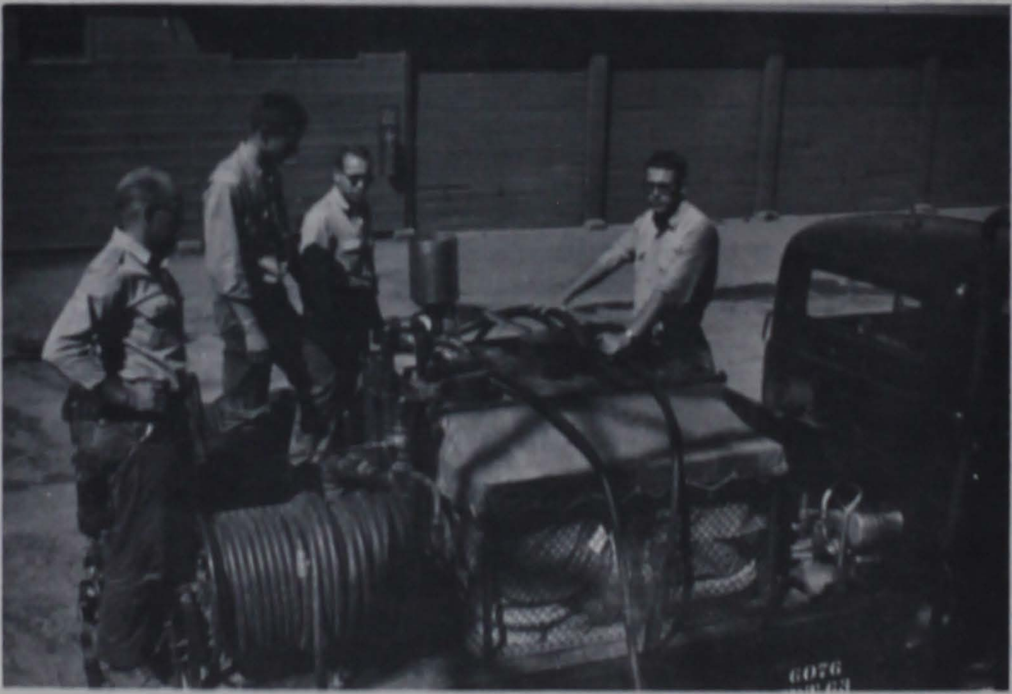

Figure 5.--Viscous water mixing equipment installed on a U. S. Forest Service fire truck at Mt. Shasta Ranger Station.

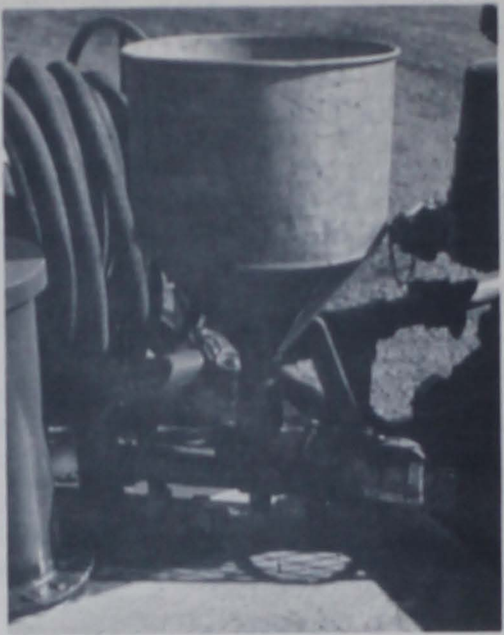

Figure 6.--
Closeup of viscous water
mixing equipment installed
on a California Division
of Forestry truck at Cathay
Fire Station.

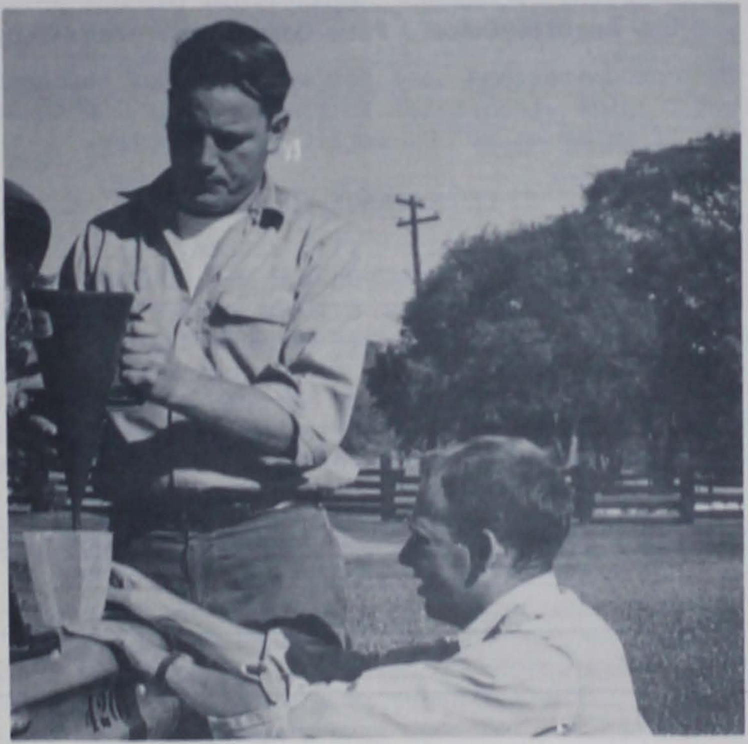

Figure 7.--Determining viscosity in the field with a Marsh funnel. The time required for the solution to run through the funnel gives an estimate of viscosity.

County), 420 gallon tank, 250 GPM pump; Paso Robles Forest Fire Station (San Luis Obispo County), 400 gallon tank, 250 GPM pump.

Viscous water--Algin, Keltex FF, Kelco Company--0.4 percent, solution in water. Tested by two U. S. Forest Service crews--Mount Shasta Ranger Station (Shasta-Trinity National Forest), 340 gallon tank, 80 GPM pump; Mohawk Ranger Station (Plumas National Forest), 400 gallon tank, 300 GPM pump; and by one California Division of Forestry crew--Flinn Springs Forest Fire Station (San Diego County), 500 gallon tank, 250 GPM pump.

ET-460-4--Dow Chemical Company--0.5 percent solution in water. Tested by one California Division of Forestry crew--Morgan Hill Fire Control Station (Santa Clara County), 400 gallon tank, 250 GPM pump.

CMC, 7-HP--Hercules Powder Company--0.5 percent solution in water. Tested by one Nevada Division of Forestry crew--Reno Fire Control Station, 160 gallon tank, 17 GPM pump.

CMC, S-75XH--E. I. DuPont de Nemours and Company--0.5 percent solution in water. Tested by one California Division of Forestry crew--Cathay Forest Fire Station (Mariposa County), 500 gallon tank, 250 GPM pump.

Algin-DAP--Diammonium phosphate, Monsanto Chemical Company--12 percent plus Keltex FF, Kelco Company--0.4 percent solution in water. Tested by one Los Angeles County Fire Department crew--Temple City.

The concentrations used for solutions of thickening agents were selected to give viscosities in the range of 100 to 400 centipoise. The viscosity of water at 20° C. is 1.005 centipoise.

PERFORMANCE ON FIRES

By the end of the forest fire season, algin had been used on 21 fires, ET-460-4 on 3, Hercules CMC on 4 fires, DuPont CMC on 2, bentonite foam on 9, and algin-DAP on 1, for a total of 40 fires. The one case where the algin-DAP was used did not provide enough information to judge its effectiveness on wild fires. Since fire occurrence for most of the cooperating stations was about 20 percent of normal, we had fewer fire tests than expected; however, the 40 fires experienced gave useful information on the effectiveness of the additives (table 2), and the five months of testing also brought out several operational problems.

Table 2.--Number of fires and effectiveness of chemical additives as reported by fire crews

Effectiveness of chemical	No. of fires
Superior to water	24
Same as water	5
Inferior to water	5
Undetermined 1/	6
Total	40

1/ For various reasons test crews could not evaluate chemical effectiveness on 6 fires.

Crews using viscous water reported a noticeable reduction in rekindling in both light and heavy fuels.

Viscous water tended to stick or cling to vertical surfaces, with an apparent good cooling and smothering effect.

Because runoff was less, viscous water usually tended to "go farther" than plain water--especially on foliage or on vertical surfaces such as walls or the trunks of trees or snags. On the other hand, in one test viscous water formed pools and did not spread over the surface of the logs and branches lying on the ground.

Viscous water was used on four structural fires with good results. Although three trucks with plain water had been unsuccessful in stopping one of these fires, it was brought under control soon after arrival of the fire truck. The material (0.4 percent Keltex FF) clung to the walls and eventually dried to a cellophane-like film. This film was thin but tough enough that it later was pulled away from the walls in sheets. There was little water damage since the viscous water did not soak into wood or fabric surfaces.

Bentonite foam appeared to be superior to water for stopping and holding fires burning in brush or small trees. It was used with good results in preparing lines for backfiring in these fuel types. Crews described it as having a blanketing effect that tended to smother the fire and insulate adjacent fuel. However, on fires in heavy grass or grain stubble, bentonite foam failed to penetrate into the matted material close to the ground. Consequently it let the fire creep underneath and eventually past the retardant line.

Both bentonite foam and viscous water reduced pumping efficiency. High pump pressures were required to produce usable nozzle pressures. However, good fog streams were produced with viscous water.

Both bentonite foam and viscous water created a clean-up and safety problem on and around the truck. Spills on the trucks are difficult to clean without removing most of the hose and loose equipment. Furthermore, the materials are slippery. Care must be taken in climbing on a truck or walking where the chemicals have been spilled. The nozzle also can become slippery and difficult to handle.

Trucks carrying water with additives have some limitations of use. For example, they cannot be used to wash down gasoline spills without producing a slippery road surface. Crews are reluctant to use bentonite foam on the inside of structures where furniture and household belongings can be salvaged; this does not seem to be a problem with viscous water. A truck which has carried bentonite foam cannot be used to haul drinking water without dumping the load and scrubbing out the tank.

CHARACTERISTICS OF FIRE FIGHTING CHEMICALS

VISCOUS WATER

The four viscosity agents used during the operational test, although different in chemical composition, work much like the powder used in making gelatine desserts at home. Since small quantities can adequately thicken the water, logistics are not a problem.

The degree of thickness depends on several factors, including the quantity and type of chemical used, temperature, salt content of the water, presence of other chemicals, and length of time that the mixed solution has been in storage.

Four to six pounds of thickening agent were required per 100 gallons of water to obtain 100 to 400 centipoise viscosities. We do not know as yet what viscosities are best, but we expect the optimum would differ somewhat with the fire situation. The early field tests indicated that suppressant effectiveness increased with viscosity, and later tests with high viscosity systems have given good results (Phillips, 1961). Test crews say viscous water below about 100 centipoise does not stick to vegetation and that above 400 centipoise gives difficulty in pumping with a centrifugal pump.

A small variation in the amount of thickening agent greatly affects viscosity of the solution (fig. 9, Appendix). For example, adding 1 pound per 100 gallons can more than double the viscosity. The viscosity of a solution with a given amount of agent may vary by nearly as much as 600 centipoise with different types of agents. The range is also due in part to variations in viscosity produced by changes in temperature--a 40-degree drop can double the viscosity.

All viscous water solutions lost viscosity in the presence of DAP. The viscosity of CMC-thickened water is greatly decreased when stored in a galvanized container which has not been coated with mastic or some other protective material. The small quantity of zinc present in galvanized pipes does not appear to be a problem.

In operational use, the viscosity of mixed solutions can easily be checked with a Marsh funnel (fig. 7) and corrected if necessary.

The viscosity agents are not toxic to animals and plants. In fact, one of the largest uses of CMC and algin is in the manufacture of food products such as ice creams and pie fillers. However, sometimes preservatives must be added to viscous water to control spoilage by bacteria during prolonged storage. These preservatives may be toxic themselves, but when added to viscous water they are so diluted that they do not present a problem (Brooks and Alyea, 1946).

The materials were found to vary considerably in corrosiveness. The alginate actually exhibited less corrosion than plain tap water to all metals commonly found on fire equipment (fig. 10, Appendix). In general, this also applied to both DuPont and Hercules CMC tested; however, both were moderately corrosive to galvanized surfaces.

The Dow ET-460-4 corroded copper and brass both in the operational test at Morgan Hill and in the laboratory. However, Dow chemists believe they have solved this problem with the addition of small quantities of a specific corrosion inhibitor. Other metals, including galvanized iron, showed little sign of corrosion.

In laboratory tests, none of the viscosity agents damaged surfaces that had been cleaned, painted, and oven-dried, even after samples were totally submerged for several weeks. Although there were several reports of "touch up" paint blistering in the field, it was probably no worse than if water had been allowed to stand on the paint for a prolonged period of time.

None of the viscous water solutions appear to be any more abrasive to pumps than plain water.

Because such small amounts of the dry powder are used (0.4 pounds per gallon of water) the weight of the solution, 8.3 pounds per gallon, is virtually the same as plain water.

CALCIUM ALGINATE GEL

Water thickened by algin to approximately 400 centipoise can be converted to calcium alginate gel by the addition of 1 part of 37 percent calcium chloride solution to about 300 parts of the algin water. The resultant gel has a viscosity of 3,500 to 5,000 centipoise. Varying the exact ratio of calcium chloride to algin determines the resultant viscosity.

BENTONITE FOAM

Swelling bentonite clay has been used with good results as a fire retardant for more than two years with air tankers. Its value as a retardant lies in its ability to set up into a stable slurry and retain water tenaciously for periods up to 2 or 3 hours under severe summer drying conditions (Phillips and Miller, 1959). When mixed with a small quantity of foaming agent such as Dowfax 2A1 and sprayed through an aerating nozzle, a stable, long-lasting foam with as much as a 7 to 1 expansion ratio can be produced.

The Dowfax 2A1 (also a wetting agent) penetrated the mastic tank lining, causing blisters that exposed the tank's metal to corrosion.

DIAMMONIUM PHOSPHATE

Diammonium phosphate is one of the more common agricultural fertilizers and is available from many sources. DAP has been recognized for many years as an excellent fire retardant and has been used extensively for structural and industrial fireproofing (Truax, 1939). Fuels treated with DAP characteristically char when subjected to an exterior source of heat but do not support flaming combustion.

The effectiveness of DAP in retarding fire appears to depend on the quantity of DAP relative to the weight and surface area of the fuel. While water solutions of DAP have been effective on grass and fine fuels, they have not been adequate to retard fires in larger fuels under severe burning conditions (Operation Firestop, 1954). Viscous water allows the DAP to stick to or remain on even heavy fuels in sufficient quantities to retard combustion.

Although DAP is not toxic, it tends to give off a slight amount of ammonia when applied to a fire. The ammonia may temporarily irritate the eyes of the nozzleman.

DAP is almost non-corrosive to mild steel, but it has proved to be somewhat corrosive to several other metals found on fire equipment, including aluminum, brass, and copper. Extent of corrosion depends largely on concentration, temperature, and length of storage. Corrosion inhibitors may solve this problem; however, little is known as yet about their effect on the viscosity of thickening agents.

MIXING, STORAGE, AND HANDLING

VISCOUS WATER

One advantage of the thickening agents tested is that only 20 pounds of any of the powdered viscosity agents per 500 gallons of water are required to produce viscosities in the range of 200 to 400 centipoise. Experienced crews find that they can mix this quantity with a jet mixer in 2 or 3 minutes, frequently while they are drafting a load of water. Although readily soluble if dispersed gradually into a jet of water, the materials form an almost impervious gelatin-like mass if poured all at once directly into a tank.

Both algin and CMC are organic compounds and are therefore subject to deterioration by bacteria when in storage. Spoilage, if it occurs, results in loss in viscosity and an odor that will make the firetruck unwelcome almost anywhere. Deterioration depends to a great degree on water source, temperature, and length of storage. It was not a problem with trucks located above 3,500 feet where temperatures were cool at night, but preservatives were necessary at stations located in the hotter foothills. About 100 parts per million of formaldehyde prevented spoilage. Laboratory samples without formaldehyde spoiled and lost viscosity within 3 weeks (fig. 11, Appendix). Eight ounces of 37 percent formaldehyde in 500 gallons of viscous water prevented spoilage in the field.

The Dow ET-460-4, unlike the other materials, is a synthetic organic compound and apparently presents no storage problem.

To insure complete mixing of the viscous solutions it is desirable to remove portions of the baffles normally used in the tanks of firetrucks. Wide openings between the compartments had to be provided to permit ease of circulation. Because of their higher viscosity, the mixed solutions do not slosh around in the tanks as does plain water and hence less baffling is needed.

This reduction in sloshing, however, results in a longer "recovery time" when the load does become unbalanced--as on curves or hills. One fire crew foreman said that his truck "rode heavier and harder" and that his springs did not seem to be adequate for the load even though none of the materials are much heavier in weight per unit volume than plain water.

CALCIUM ALGINATE GEL

Mixing of calcium alginate gel takes place in the nozzle. Algin thickened water is pumped through the hose as usual. In the tests, the calcium chloride solution was contained in small pressurized tanks in a backpack weighing about 20 pounds which was carried by the nozzleman (fig. 8). A 1/8 inch hose conducted the calcium chloride to the nozzle, where a valve operated by the nozzleman controlled the amount mixing with the algin thickened water. The two solutions form a gel immediately.

This mixing arrangement caused no additional loss in hose or nozzle pressure and permitted the application of straight or fog streams. By use of the calcium chloride control valve at the nozzle, the nozzleman could change quickly from viscous water to gel and back again, according to the fire situation. He could also control the viscosity of the gel by changing the valve opening.

The mixing arrangement is still in a crude developmental stage. Further refinement may produce a more convenient and more efficiently operated apparatus.

BENTONITE FOAM

Bentonite foam was mixed in much the same manner as viscous water. Logistics was more of a problem because 250-300 pounds of dry bentonite had to be mixed into the truck's water supply of 500 gallons and then a gallon of Dowfax 2A1 foaming agent added.

The top of the truck's tank was removed and replaced with inspection doors. Large holes were cut in the baffles, and new plumbing installed in the trucks so that the bentonite slurry could flow and circulate easily and uniformly throughout the tank. After the bentonite was thoroughly mixed by the jet, the foaming agent was

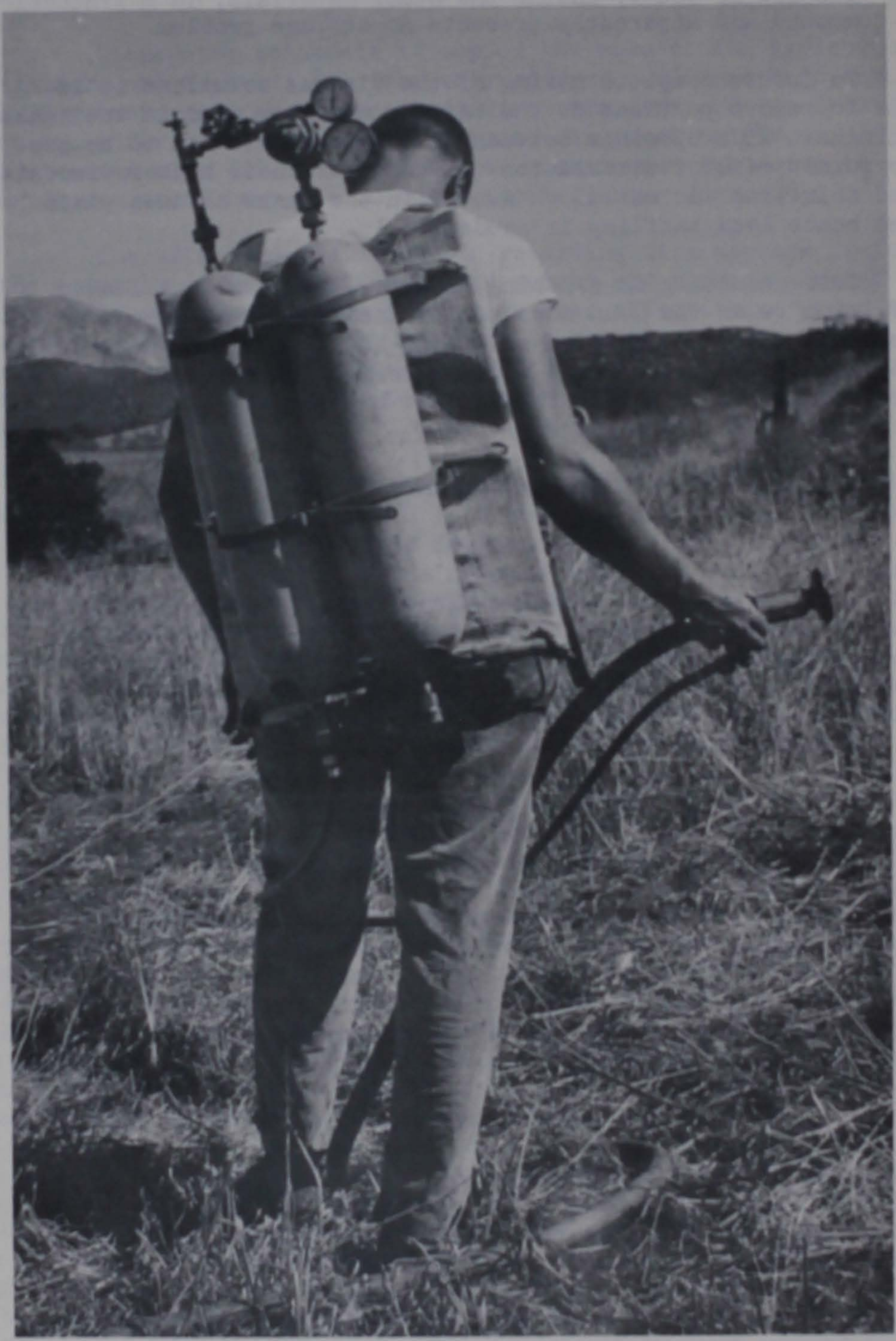

Figure 8.--Backpack arrangement and nozzle used to mix calcium chloride to algin to form calcium alginate gel.

poured through one of the inspection doors and stirred with a shovel. The mixture was then recirculated for a few minutes. Almost no foaming takes place during this recirculation if air entrainment is prevented.

DIAMMONIUM PHOSPHATE

DAP mixes readily with plain water or water thickened with CMC or algin, but it reduces viscosity a great deal within a few hours. This can be overcome by adding additional quantities of thickening agents.

COSTS

Viscous Water.-- The various thickening agents cost from 60 cents to a dollar per pound; 0.5 to 0.7 percent solutions cost about 2.5 to 7 cents per gallon.

Calcium Alginate Gel.--Since calcium chloride is inexpensive and little of it is used to make a gel, the cost per gallon of calcium alginate gel is virtually the same as for water and algin alone.

Bentonite Foam.--Bentonite slurry costs about 1.5 cents per gallon for the dry powder. The foaming agent adds about 1 cent per gallon, making a total of 2.5 cents per gallon for the bentonite foam mixture prior to expansion.

Viscous DAP.--Diammonium phosphate costs about 6 cents per pound. Mixed at the rate of 1-1/2 pounds per gallon to viscous water costing 3 to 4 cents per gallon, viscous DAP costs 12 to 14 cents.

CONCLUSION

These observational tests have left many unanswered questions. Particularly, we need more information on suppressant and retardant effects of these chemicals under different burning conditions and on different fuel types. However, results have been sufficiently uniform to draw several preliminary conclusions.

Viscous water reduced suppression time under several conditions and kept fires from rekindling. Although there were operational difficulties such as spoilage and slight corrosion of metal parts, most problems can probably be solved. The dry powder that makes the water thick can be mixed on the fireline in 1 to 5 minutes with a jet-type mixer which is easily installed on the truck.

Tests of calcium alginate gel, though done late in the year, look promising. The material will be tested on actual forest fires in 1961.

Bentonite foam also gave good results in knocking down the spread of brush fires and building backfire lines. But this material failed to penetrate heavy grass or grain stubble and did not stop fires in these fuels.

Diammonium phosphate has shown promise as a retardant in field tests, but has not been evaluated on wild fires.

The price is reasonable for all of these chemicals, ranging from 3 to 14 cents per gallon.

Future plans call for expanding the operational testing program to include more fire control crews and to cover more fuel types. Emphasis will be centered on viscous water and gel. Simultaneously, equipment development studies and laboratory research will be conducted to make sure that field crews have the latest information on equipment and techniques.

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APPENDIX--SUMMARY OF GROUND TANKER USE--1960

Number, name, and date of fire	Station	Fuel	Burning index 1/	Chemical	Effect and Comments
1. Star 7-11-60	Mariposa-CDF	Grass	Not available	Bentonite foam	"Better for line building."
2. No name 7-12-60	Morgan Hill-CDF	Grass	-20	ET-460-4	"Sticks to material well."
3. Hotlum 7-13-60	Mt. Shasta-USFS	Grass and sage	14	Algin	"Better than water."
4. No name 7-14-60	Paso Robles-CDF	Grass	Not available	Bentonite foam	"Water better for grass." "Chemical does not penetrate."
5. No name 7-14-60	Mt. Shasta-USFS	Second growth-poles	14	Algin	"Small mopup job--water would have done as well."
6. No name 7-14-60	Paso Robles-CDF	Med. brush and oak--So. Calif.	Not available	Bentonite foam	"Adheres better than water."
7. Polecat 7-17-60	Temple City-LACFD	Heavy mixed brush	27	Algin-DAP	No information--Had to evacuate entire area.
8. NP-31339 7-23-60	Mt. Shasta-USFS	Woodland	12	Algin	Fire was stopped. "Chemical superior to water."
9. Raner 7-26-60	Mohawk-USFS	Sawdust and lumber	17	Algin	"Chemical has definite cooling and smothering effect."

Number, name, and date of fire	Station	Fuel	index 1/	Chemical	Effect and Comments
10. Hornitos Sch. 8-1-60	Cathay-CDF	Grass	Not available	CMC	"Has more cooling effect."
11. High 8-7-60	Mt. Shasta-USFS	Second growth-poles	15	Algin	Fire was stopped. "Unable to determine."
12. Cemetery 8-13-60	Mt. Shasta-USFS	Brush mixed with sage	14	Algin	"Chemical better than water."
13. Sawdust 8-14-60	Mt. Shasta-USFS	Sawdust	16	Algin	"Algin solution did not penetrate sawdust as well as water."
14. SPRR#6 8-17-60	Morgan Hill-CDF	Grass	Not available	ET-460-4	"Highly corrosive to metals and paint." "Same as water." "Hard to work with."
15. Peavine 8-18-60	Reno-NDF	Grass, sage	30	CMC	"Better smothering effect--no nozzle distance."
16. Schilling 8-20-60	Mt. Shasta-USFS	Mixed fir reproduction and brush	28	Algin	Fire was stopped. "Chemical as good or better than water."
17. Running Burn 8-20-60	Mariposa-CDF	Woodland	15	Bentonite foam	"Has blanket effect."
18. Homestake Mine 8-20-60	Morgan-Hill-CDF	Timber med. repro. and brush.	24	ET-460-4	"Forms pools--does not spread."

Number, name, and date of fire	Station	Fuel	Burning index 1/	Chemical	Effect and Comments
19. Donner Ridge 8-20-60 8-27-60	Reno-NDF	Timber med. reproduction and brush	70	CMC	"Has better suffocating effect but takes too long to mix--reduces nozzle stream."
20. Donner Ridge 8-29-60	Reno-NDF	Timber med. reproduction and brush	60	CMC	"Pump doesn't have enough pressure." "Has good coating effect."
21. Carney 8-30-60	Paso Robles-CDF	Structure	Not available	Bentonite foam	"Better than water." "Has ability to hold water."
22. Eagle Ranch 9-7-60	Paso Robles-CDF	Grass	26	Bentonite foam	"Equal to water."
23. Cartwright 9-7-60	Flinn Springs-CDF	Grass	10	Algin	"No real test."
24. Cowan 9-9-60	Flinn Springs-CDF	Baled hay	18	Algin	"Held moisture in hay."
25. Gilzean 9-9-60	Mt. Shasta-USFS	Brush mixed with sage	7	Algin	"Helped hasten the cooling down of the fire by slower evaporation."
26. Feus Flat 9-9-60	Mohawk-USFS	Mixed fir reproduction and brush	19	Algin	"Chemical has cooling effect, but does not penetrate."
27. Raymond "Y" 9-11-60	Cathay-CDF	Grass	28	CMC	"Prevents rekindling better than water."

Number, name and date of fire	Station	Fuel	Burning index 1/	Chemical	Effect and Comments
28. Sample 9-11-60	Flinn Springs-CDF	Structure	18	Algin	"Fire knocked down held."
29. MP-338 9-15-60	Mt. Shasta-USFS	Grass	19	Algin	"Plain water would have been as effective."
30. Krool 9-17-60	Mt. Shasta-USFS	Mixed fir reproduction and brush	19	Algin	"No better than water."
31. San Vicente 10-5-60	Flinn Springs-CDF	Med. brush and oak	14	Algin	"Algin slippery to work with but no rekindling."
32. No name 10-14-60	Reno-NDF	Piled logs	Not available	CMC	"No better than water."
33. Mi. Post 248.69 10-15-60	Paso Robles-CDF	Grass	11	Bentonite foam	"Same as water."
34. Brannon 10-16-60	Flinn Springs-CDF	Structure	18	Algin	"Mopup with chemical worked well."
35. Smith 10-17-60	Paso Robles-CDF	Woodland	21	Bentonite foam	"Seems to hide deep bedded fires." "No good for mopup."
36. Rossi #2 10-19-60	Paso Robles-CDF	Dump	11	Bentonite foam	"Sticks to trash." "Better than water."
37. Tilton 11-10-60	Flinn Springs-CDF	Structure	Not available	Algin	"Kept fire knocked down."

Number, name, and date of fire	Station	Fuel	Burning index 1/	Chemical	Effect and Comments
38. Guthrie 11-15-60	Flinn Springs-CDF	Structure	Not available	Algin	"Good cooling effect."
39. Huff 12-17-60	Flinn Springs-CDF	Truck load of furniture	Not available	Algin	"Algin solution was coating surface eliminating fuel for fire--did not damage furniture."
40. Tarbert	Flinn Springs-CDF	Structure	Not available	Algin	"Cooling and sticking effect." "Did not soak in--stopped fire without water damage."

1/ Burning Index Ranges: Low = 0 to 5; Moderate = 6 to 11; High = 12 to 18; Very high = 18 to 26; and Extreme = 27 to 100.

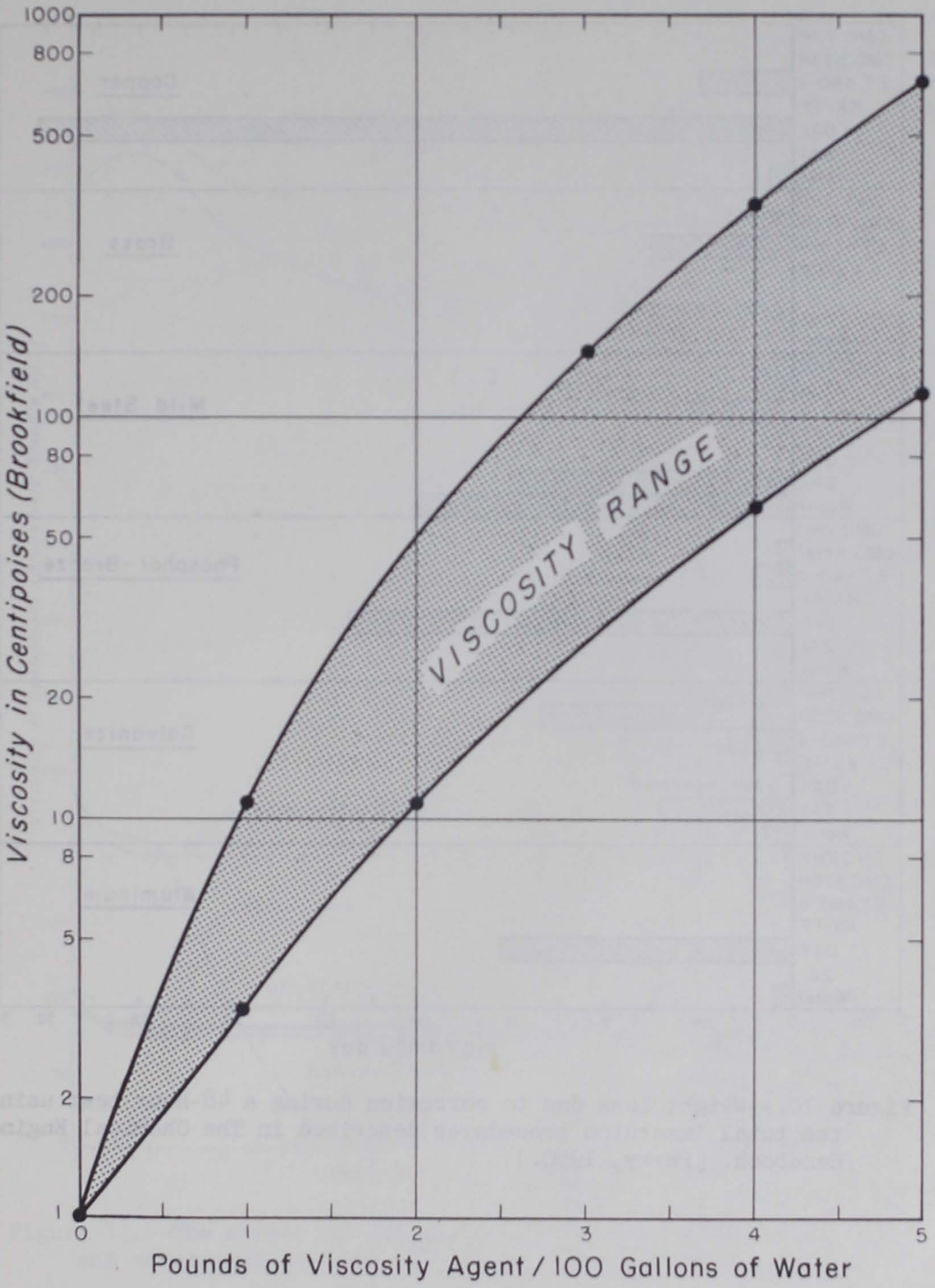

Figure 9.--Range of viscosities obtained with chemicals used during operational testing. Curves plotted from laboratory data obtained at the Pacific Southwest Forest and Range Experiment Station and from information supplied by manufacturers.

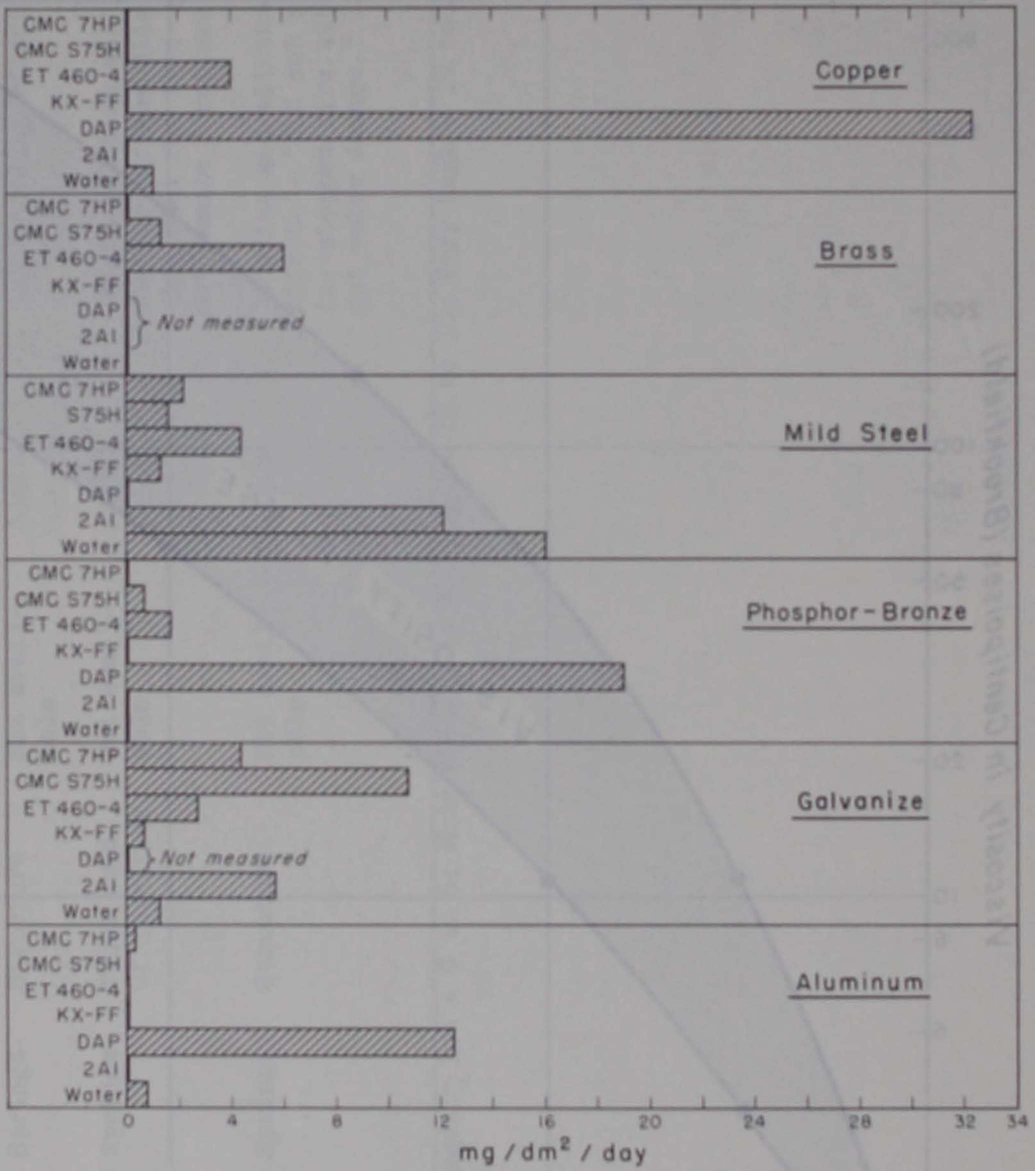

Figure 10.--Weight loss due to corrosion during a 48-hour test using the total immersion procedures described in The Chemical Engineer's Handbook. (Perry, 1950.)

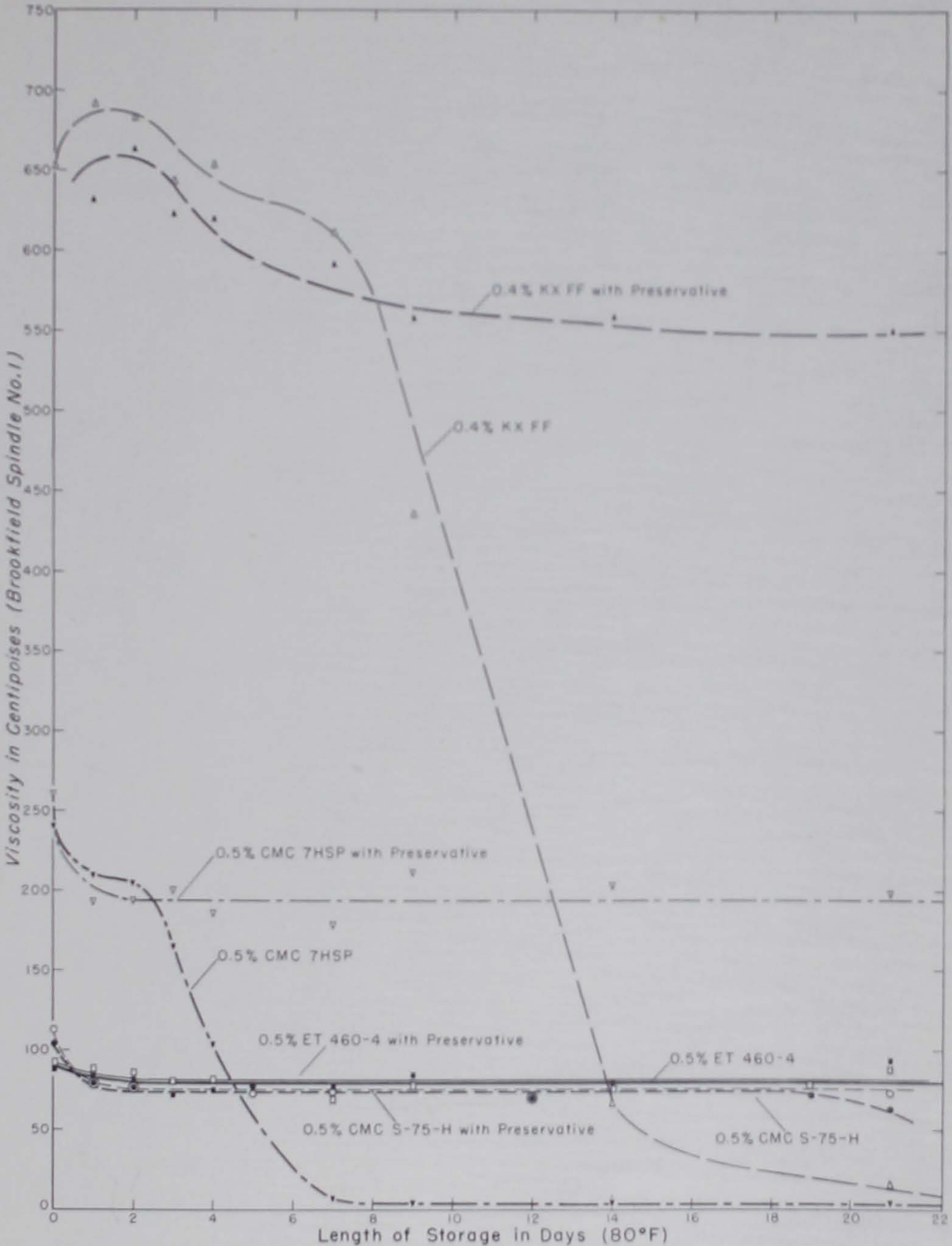

Figure 11.--The effect of 100 ppm formaldehyde in preventing spoilage and associated loss in viscosity (2.8 liter samples held at 80°F).

MISCELLANEOUS PAPER No. 58
AUGUST 1961

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PROMISING GRASSES FOR SOUTHERN CALIFORNIA FUEL-BREAKS

George C. Edmunson, Jr.
Donald R. Cornelius

PACIFIC SOUTHWEST
FOREST AND RANGE
EXPERIMENT STATION
BERKELEY - CALIFORNIA

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

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Miscellaneous Paper No. 58 August 1961

U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
Berkeley, California

PROMISING GRASSES FOR SOUTHERN CALIFORNIA FUEL-BREAKS

By
George C. Edmunson, Jr.[1]
and
Donald R. Cornelius[2]

Control of any large brush fire in southern California is difficult, dangerous, and very costly. Great expanses of dense, highly flammable brush, a dry summer climate, spells of hot, windy weather, and steep, rough topography underlie these difficulties. The brush cover can be modified, accessibility greatly improved, and fire control made easier by the establishment of fuel-breaks. These are grass-covered strips 200 to 600 feet wide, which break up the brush fields and improve their accessibility to men and equipment.

Some grass species are widely adapted and can be rather easily established in place of the brush. Others are more limited but are useful under specific conditions. This paper describes the conditions under which several grasses have performed satisfactorily over the past few years.

Grasses appear most satisfactory of the plants tested for revegetating large acreages because seed of many grass species is commercially available, techniques for sowing have been developed, and a few species already have proved to be adapted to sites in southern California. In addition, grasses sown during the conversion process are not damaged by the selective sprays used to eradicate regrowth of native shrubs.

A grass cover is suitable on fuel-breaks because it allows easy access for firefighters, and because fire in grass can be readily controlled. It is not always an ideal cover, however, because fire can spread rapidly in dry mature grass. Plants which stay green as long as possible in the fall, as do many of the perennial grasses, are preferable for fuel-break cover.

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For southern California foothills and lower mountains, Hardinggrass and smilo have been recommended as two basic perennial grasses.[3] Both of these species had survived well in tests by Department of Agriculture agencies and the University of California--both of these species produced large vigorous plants, superior to all other species. Veldtgrass was recommended to replace part of the Hardinggrass on light-textured soils. Wheatgrasses were recommended for trial at elevations too high for Hardinggrass, particularly on the desert side of the mountains. Little information on species adaptation was available for these sites.

Plots sown by the Agricultural Research Service in 1956[4] on burned areas in the San Bernardino National Forest confirmed that Hardinggrass grew poorly above about 3,500 feet elevation, but wheatgrasses were adapted at this elevation and grew well at higher elevations. This report gives the results from recent tests in southern California mountains and brings up-to-date the recommendations for grasses to sow on cleared brushlands in that region. The tests were conducted in the 1958-59 and 1959-60 growing seasons as part of the FUEL-BREAK program.[5] The Pacific Southwest Forest and Range Experiment Station is testing the adaptation of commonly used species to different sites, and is cooperating with the Forage and Range Research Branch of the Agricultural Research Service and with the University of California in a study of new species and strains. Seed of some noncommercial species is supplied by the Plant Materials Center of the Soil Conservation Service. The University of California also supplied part of the seed of commercial species on two large areas.

THE PROBLEM AREA

The area directly concerned in this report extends southward from central San Luis Obispo County along the coast to the Mexican border. It includes all of the coastal mountains, but not the southern part of the San Joaquin Valley, the Mojave Desert, nor other deserts of southeastern California. The Cleveland, San Bernardino, Angeles, and Los Padres National Forests are included.

It is a region of extremely steep topography. High, youthful mountains are dissected by deep V-shaped valleys. Soil over most of the area is shallow, sandy loam. Elevations range from sea level to nearly 11,500 feet.

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[3] Bentley, J. R., L. J. Berry, D. R. Cornelius, and R. M. Love. Range species recommended for sowing on cleared brushland in California. U. S. Forest Serv. Calif. Forest and Range Expt. Sta. Res. Note 111, 9 pp. 1956.

[4] Office report by D. R. Cornelius, Agricultural Research Service, Berkeley, California.

[5] A cooperative program organized by three of the major fire-fighting agencies in southern California--California Division of Forestry, Los Angeles County Fire Department, and U.S. Forest Service.

The climate in southern California is generally warm and dry with winter precipitation and hot, droughty summers. Precipitation varies from about 10 inches at low elevations and in rain-shadows of mountains to 35 inches or more at high elevations (table 1), but during this 2-year study rainfall was about half of normal at plot locations.

Native brush cover over much of this area is dominated by chamise on the south slopes and scrub oak on the north. The chaparral also has various species of other shrubs, including sages, sumac, ceanothus, mountain mahogany, and manzanitas.

Grazing by domestic livestock, mainly cattle, is an important use of the mountainous areas in San Luis Obispo, Santa Barbara, and Ventura counties. Farther south, where the terrain is more rugged, less of the land is grazed by livestock, and watershed values are dominant.

Table 1.--Average monthly and annual rainfall in southern California

Month	Tanbark Angeles NF	Barrett Dam Cleveland NF	Raymond Flats San Bernardino NF	Ozena Los Padres NF
	Inches			
Sept.	0.28	0.36	0.99	0.18
Oct.	1.13	.64	1.62	.48
Nov.	2.07	1.21	2.57	.81
Dec.	4.99	3.43	6.79	2.60
Jan.	5.33	3.14	5.26	2.38
Feb.	5.75	3.64	7.18	2.35
Mar.	4.23	3.01	5.22	2.13
Apr.	2.56	1.53	2.23	.85
May	.56	.38	.58	.30
June	.13	.05	.16	.04
July	.004	.09	.62	.07
Aug.	.08	.23	1.02	.10
Annual	27.11	17.71	34.24	12.29
Elev., feet	2,720	1,623	7,070	3,705
Reseeding zone[1]	6	4	8	10

[1] For description of zones see table 2.

PROCEDURE

RESEEDING ZONES FOR GRASSES

Climate and soil, two major factors determining the distribution of native vegetation, will no doubt similarly effect the growth and adaptation of introduced grasses. The problem area was divided into 10 reseeding zones (table 2) logically based on plant growth requirements and limitations. These zones will be used initially in recommending species for reseeding. Soil groupings will be added to zone characteristics after soils information has been obtained.

Seven of the zones average more than 15 inches precipitation annually and are considered suitable for tests of perennial grasses. The mild coastal area divides into two zones, one with more than and one with less than 15 inches precipitation. This area has a mild moderate climate, little frost, and a long growing season.

Table 2.--Tentative southern California reseeding zones[1]

Reseeding zone	Climatic influence	Average precipitation	Elevational range
		Inches	Feet
1	Coastal	10-15	Below 1,500
2	Coastal	15-25	Below 3,500
3	Inland mountain	10-15	500-3,500
4	Inland mountain	15-25	500-3,500
5	Inland mountain	15-25	3,500-6,500
6	Inland mountain	25-35	2,000-3,500
7	Inland mountain	25-35	3,500-5,000
8	Inland mountain	25-45	5,000-8,000
9	Desert	15-25	3,000-9,000
10	Desert	10-15	2,500-8,000

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[1] From Edmunson, "Climatic zones for reseeding grasses on southern California Fuel-breaks." U.S. Forest Serv., Pacific Southwest Forest and Range Experiment Station. (File report.)

The inland valleys and mountains include six zones, five with more than 15 inches of precipitation, one with less. The three inland zones with 15 to 25 inches rainfall are too dry for all but drought-tolerant grasses, but those with 25 inches or more are considered adequate for several additional species. Elevations below 3,500 are considered suitable for low elevation grasses, those between 3,500 to 5,000 feet for medium elevation grasses, and those above 5,000 feet for high elevation species. Daily and yearly temperatures fluctuate considerably in these inland zones. Frost occurs occasionally at lower elevations in the winter and frequently at medium elevations along with occasional snowfall. At higher elevations snow frequently remains on the soil winterlong.

The area bordering the desert and in the rainshadows of high mountains has been separated into two zones, one with more and one with less than 15 inches of precipitation. The climate in this area is desert-like--dry and desiccating--and temperatures fluctuate considerably.

SEEDING METHODS

Drilling and broadcasting were compared for each of 16 grass species, in 7 of 11 fuel-break study areas. Three areas could not be drilled, and on one drilling was the only planting method used. A small grain drill, 3 feet wide and with rows 7 inches apart, was pulled behind a pickup truck on most seeding plots. The rangeland drill, 10 feet wide and with rows 1 foot apart, was pulled by track-type tractors for drilling experiments when it was available. The single disk coulters with depth bands provided a desirable depth and covering for the seed. Broadcasting of seed on the experimental plots was by hand to give results comparable to seeding from a plane or helicopter normally used on large scale seedings.

DATA COLLECTION

Plant counts were made on square-foot quadrats, to determine emergence the first year and survival the second year after sowing. Plant vigor and stand densities were noted. Table 3 summarizes plant counts at four representative study areas.

PERFORMANCE RATINGS

The performance of species was evaluated on the basis of emergence, survival, and plant vigor during the 2-year period. These evaluations are the basis for current fuel-break recommendations; they will be reviewed and revised if necessary after additional observation.

Table 3.--Average number of plants per square foot after seeding at four fuel-break study areas

Species	El Cariso		Paradise		Reservoir Summit		Monrovia	
	Zone 2		Zone 4		Zone 5		Zone 6	
	1st yr.	2d yr.	1st yr.	2d yr.	1st yr.	2d yr.	1st yr.	2d yr.
Perennials								
Blue wild rye	4.3	0.5	4.8	0.5	17.7	2.1	4.8	0.5
Big bluegrass	6.0	.1	9.3	.1	3.7	.5	1.5	.2
Goar fescue	2.7	.0	9.3	.8	2.7	.9	.7	.1
Hardinggrass	3.3	.2	5.3	1.7	3.7	.1	.3	.2
Nodding stipa	2.7	.8	6.3	3.2	3.0	1.2	1.7	.5
Orchard (Commercial)	6.3	.2	4.0	.4	11.7	.7	4.0	.4
Orchard (Palestine)	4.7	.2	1.8	.2	9.0	1.2	1.8	.2
Smilo	.7	.0	1.0	.4	1.7	.4	.8	.0
Veldt grass	3.0	.0	12.7	.2	1.3	.0	1.8	.2
Crested wheatgrass	3.0	.0	7.7	.5	8.3	3.2	1.5	.2
Intermediate wheatgrass	2.7	.0	3.3	1.0	1.3	(1/)	1.7	.2
Pubescent wheatgrass	1.3	.1	6.7	.8	1.0	(1/)	1.0	.2
Tall wheatgrass	2.3	.2	4.3	1.1	2.7	1.4	2.2	.5
Annuals								
Annual ryegrass	10.0+	8.9+	9.7+	10.0+	2.7	(1/)	7.2	10.0+
Blando brome	4.0	7.7	9.0	10.0+	10.0+	(1/)	3.7	4.1+
Cereal rye	1.3	1.4	3.7	.7	1.3	.1	1.0	1.4

1/ Plants injured by tractor.

+ Indicates there were more than 10 plants in one or more quadrats and that the counts did not go beyond 10.

RESULTS

THE WHEATGRASSES

Five years ago, the potential of the wheatgrasses in southern California was not generally recognized, but they have done surprisingly well in recent years and are recommended for most mixtures in upper elevations. They also are included in some lower elevation seeding mixtures.

Tall wheatgrass.--Tall wheatgrass has been outstanding among wheatgrasses. It rated good to excellent in all zones where perennial grasses were considered adaptable (table 4). It has done best with 15 to 35 inches of rainfall at elevations above 3,500 to 6,500 feet. In Zone 5 it formed a better ground cover than any other grass. In Zone 7, it was second only to intermediate wheatgrass. Tall wheatgrass is a long-lived, drought-tolerant introduced bunchgrass. It stays green, or partially green, late in the season--an important consideration in fire control. It is also stemmy and coarse leaved. Seed is commercially available at moderate price.

Intermediate wheatgrass.--This grass has done best at medium and higher elevations, 4,000 to 8,000 feet, and with rainfall of 20 to 40 inches. In Zone 8 it was rated the best grass. In somewhat drier and lower Zones 4 and 5, intermediate wheatgrass did well on good deep soil, but was inferior to other grasses on dry sites. Intermediate wheatgrass is a long-lived, introduced perennial grass which is capable of slow spread by rhizomes. It stays green later in the season than most perennials but not as late as tall wheatgrass. Seed is commercially available.

Pubescent wheatgrass.--This grass has grown well over a wide range of elevation and rainfall, but it usually was not as vigorous as either tall or intermediate wheatgrasses where they are adapted. In Zone 9 on the desert side of the mountains, however, it grew better than either, and better than any other grass. It has not grown satisfactorily below 2,000 feet elevation, or with less than about 15 inches of rainfall. Pubescent wheatgrass is another drought-tolerant, introduced perennial. It grows on somewhat less fertile sites than tall or intermediate wheatgrasses, which it resembles. It tends to fill in bare soil with new plants from rhizomes. Seed is commercially available.

Crested wheatgrass.--Crested wheatgrass, better known among the wheatgrasses for drought resistance, has done well in our tests at elevations between 3,500 and 6,500 feet, and with rainfall between 15 and 25 inches. Although not most outstanding in any zone, it looked good in Zones 5, 7, 8, and 9. It has not grown well at low elevations in the coastal or inland mountain climatic influences. Crested wheatgrass has a shorter growth period and less height than the other wheatgrasses and has not provided as good a ground cover. Seed is usually abundant.

Table 4.--Ratings of grasses, based on comparative growth in southern California, 1958-1960

Species	Performance in reseeding zones [1]						
	2	4	6	7	5	8	9
PERENNIAL GRASSES							
Long-lived grasses							
Tall wheatgrass	G	E	G	E	E	G	E
Intermediate wheatgrass	F	G	F	E	G	E	E
Pubescent wheatgrass	F	G	F	G	G	G	E
Crested wheatgrass	F	F	F	E	E	G	G
Nodding stipa	E	E	E	G	G	F	P
Blue wild rye	E	F	E	G	G	F	F
Hardinggrass	G	E	G	F	P	P	P
Smilo	F	F	F	P	G	P	P
Goar fescue	F	F	G	G	G	F	P
Short-lived grasses							
Veldt grass	F	P	P	P	P	P	P
Orchardgrass (Commercial)	F	P	F	F	F	F	P
Orchardgrass (Palestine)	F	P	F	F	F+	F	P
Big bluegrass	F	P	F	F	F	G	G
ANNUAL GRASSES							
Soft chess (Blando brome)	E	E	G	F	G	P	P
Annual ryegrass	E	E	E	G	F	F	P
Cereal rye	G	G	G	G	G	G	G

---

[1] Species were not rated in zones 1, 3, and 10, where yearly precipitation is only 10-15 inches and where most of the perennials may not be adapted.

Ratings: E = Excellent, G = Good
F = Fair, and P = Poor

OTHER LONG-LIVED PERENNIAL GRASSES

Three introduced, and two native range grasses were tested in this group. All have been used in reseeding rangeland in California.

Hardinggrass.--This grass is planted more widely than any other on low elevation rangeland in California. In southern California it rated good to excellent in the lower zones and poor above 3,500 feet. Hardinggrass grew best in Zone 4, but also did well in Zones 2 and 6. Hardinggrass is a long-lived introduced bunchgrass. It grows 3- to 4-feet high on fuel-breaks, and matures after nodding stipa but before the later-maturing intermediate and tall wheatgrasses. After maturing, stems are frequently green near the base. Seed is available but expensive.

Smilo.--This has been a tough long-lived grass on a variety of sites. Although rarely recommended alone it has been a standard component in seed mixtures for low-elevation brushland seeding for several years. It serves a purpose in mixtures because of its superior ability to establish on hard soil where coverage of seed is difficult. Seedlings develop slowly in winter because smilo grows best during warm weather. In our tests smilo has done best at medium or low elevations with 15 to 35 inches of rainfall, but it has not excelled over other grasses. Although stands at the study areas have been erratic and generally poor in the past two years, smilo is included in some of the recommended grass mixtures because of its good growth and persistence in earlier trials.

Nodding stipa.--The grass with the best growth record below 3,500 feet and with 15 to 25 inches of rainfall was nodding stipa. Between 3,500 and 5,000 feet elevation in Zones 5 and 7 it has also done well, but was rated behind the wheatgrasses. At the higher elevations and under the desert climatic influence it grew poorly. Nodding stipa is a long-lived, very drought-tolerant, small bunchgrass native to the coastal mountains and Sierra foothills in California. It survives where most other perennials do not. On this attribute, it would be used considerably on fuel-breaks were seed commercially available.

Blue wildrye.--This is another native species that has given fair to good results at low to medium elevations and moderate rainfall in the mountains, and near the ocean. Within its zone of adaptation seedling stands have been good, and second-year survival better than in most species. Experience elsewhere in California indicates that plants generally remain small. No commercial seed supplies are available, however, so it cannot be recommended for fuel-break seeding.

Goar fescue.--This is an early maturing, vigorous strain of the tall fescue commonly planted in irrigated pasture mixtures. In our tests it has grown moderately well in Zones 5, 6, and 7, or between 2,000 and 5,000 feet elevation with a rainfall of 25 inches or more at the lower elevations. Even where it is best adapted, plants are not as hardy as those of other adapted grasses such as harding or tall wheatgrass.

SHORT-LIVED BUNCHGRASSES

Several short-lived bunchgrasses are being tested. None has been outstanding.

Orchardgrass.--Two strains of orchardgrass, commercial and Palestine, were seeded at each site. Differences between them are small, and we judge them of about equal usefulness on fuel-breaks. Both have produced good seedling stands, but second-year survival has been poor in these dry years. Additional study is necessary before we can recommend orchardgrass.

Veldt grass.--This is a short-lived introduced bunchgrass whose numbers have declined from good seedling stands to a few scattered or no plants in the second year. It has not proved adapted for fuel-break seeding, especially above 2,000 feet.

Big bluegrass.--The Sherman strain of big bluegrass is a small short bunchgrass. It does not appear widely adapted to the dry soils of southern California. It shows greatest promise on north exposures above 25 inches of rain and 5,000 feet elevation. Seed is commercially available.

ANNUAL GRASSES

Annual grasses are tested for fuel-breaks because they produce a quick cover, are more easily established than perennials from broadcast seeding, and may be the only species adapted on poor sites. Annual grasses dry out earlier and usually present more flammable fuel than perennial grasses. These species rely upon self-seeding for perpetuation. Two forage grasses and one cereal have been studied.

Soft chess.--This is a rapid-growing, drought-tolerant annual grass. It matures earlier and is better suited for quick vegetal cover on droughty soils than commercial ryegrass, but it dries early, and has fine stems and leaves through which fire can move rapidly. Soft chess is an excellent annual to seed in light amounts with a perennial mixture because it does not compete strongly and will add to the ground cover. Seed of soft chess is commercially available as "Blando brome." In our tests, soft chess was rated "excellent" at the lower elevations near the coast and also inland. Its growth was fair at medium elevations and poor at high elevations.

Commercial annual ryegrass.--This is a rapid developing moderately drought-tolerant, introduced annual grass. It seeds abundantly and perpetuates itself for a few years on north exposures. Thereafter, vigor and coverage decline, and it fails to persist. On good sites it competes aggressively with perennials, and should not be drilled with them. Annual ryegrass is rather coarse stemmed. Seed is the cheapest of the grasses. Annual ryegrass has grown very well in Zones 2, 4, and 6, up to about 3,500 feet elevation on the coastal side of the mountains where rainfall is between 15 and 30 inches. Growth at higher elevations was less vigorous. On the desert side of the mountains the growth was poor.

Wimmera ryegrass.--This ryegrass has been planted alongside commercial ryegrass on several sites and consistently has grown as well the first year. The second year, on a dry site, wimmera was considerably better than commercial ryegrass. On a site with deeper soil and north exposure there was little difference in growth. On drier, harsher sites in southern California wimmera ryegrass should be substituted for commercial annual ryegrass in fuel-break sowing.

Cereal rye.--Cereal rye rated fair to good on all sites. Because it is tall and stemmy, competes excessively with perennials the first year, and persists poorly, cereal rye is not recommended for fuel-break seeding.

RECOMMENDED SPECIES MIXTURES

Tentative species mixtures recommended for sowing in the various zones are shown in table 5. Results from our trials during only two years, when precipitation each year was about half of the longtime average, have been used to modify previous recommendations. Some species for which seed is not commercially available, or is in short supply, have been omitted.

Species testing, now concentrated on the San Dimas Experimental Forest, also will be continued elsewhere in southern California to refine the species recommendations.

SUMMARY AND CONCLUSIONS

Tests of grasses have been underway for two years under a variety of southern California soil and climatic conditions in coastal and inland mountain areas. The objective is to select species for sowing on southern California fuel-breaks and other areas.

Thirteen perennial and three annual grasses were planted in a total of seven different climatic zones. On most sites they were both drilled and broadcast. Grasses were rated for emergence during first season, survival through the second year, and stand development characteristics.

Wheatgrasses proved to be highly suitable for southern California fuel-break seeding. They are the most important grasses for higher elevations and are also useful components for lower mountain seeding mixtures. Tall wheatgrass appeared most useful and proved to be widely adapted. Hardinggrass grew well below elevation of 3,500 feet on deep soil receiving at least 15 inches average annual rainfall.

Table 5.--Mixtures recommended for 7 different zones in the southern

California fuel-break program

Climatic zones	Grass species	Drilling ra Lbs.per acre
2--Coastal, 15-25 in. precipitation, below 1,500 feet elevation 4--Inland mountain, 15-25 in. precipitation, below 3,500 feet elevation	Hardinggrass	2
	Tall wheatgrass	2
	Pubescent wheatgrass	1
	Blando brome	1/4
5--Inland mountain, 15-25 in. precipitation, 3,500 to 6,500 feet elevation	Tall wheatgrass	2
	Crested wheatgrass	2
	Pubescent wheatgrass	1
	Blando brome	1/4
6--Inland mountain, 25-30 in. precipitation, 2,000 to 3,500 feet elevation	Hardinggrass	2
	Tall wheatgrass	2
	Intermediate wheatgrass	1
	Pubescent wheatgrass	1
	Smilo	1
	Blando brome	1/4
7--Inland mountain, 25-30 in. precipitation, 3,500 to 5,000 feet elevation	Tall wheatgrass	2
	Intermediate wheatgrass	2
	Pubescent wheatgrass	1
	Blando brome	1/2
8--Inland mountain, 25-45 in. precipitation, 5,000 to 8,000 feet elevation 9--Desert-side mountain, 15-25 in. precipitation, 3,000 to 9,000 feet elevation	Intermediate wheatgrass	2
	Tall wheatgrass	2
	Pubescent wheatgrass	1
	Crested wheatgrass	1

1/ For broadcast seeding, double these rates.

Several species--Goar fescue, orchard grass, veldt grass, smilo, and big bluegrass--produced less satisfactory growth than did wheatgrasses or hardinggrass. Of the native species, nodding stipa and blue wild rye rated highly but seed of these species is not commercially available.

Soft chess (Blando brome) proved suitable for seeding on most sites at medium to low elevations. It may be sown in small amounts with perennials. Commercial annual ryegrass grows aggressively on good sites and provides excellent ground cover for a few years after brushland is burned over. It can compete with perennial grasses severely during the establishment period and is not recommended for sowing with them. Wimmera ryegrass grew as well as commercial ryegrass, and may be substituted for it.

Tentative species mixtures have been recommended for the climatic zones in southern California.

MISCELLANEOUS PAPER No. 59
AUGUST 1961

TESTING AND EVALUATING CHEMICAL FIRE RETARDANTS IN THE LABORATORY

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D. L. Dibble
S. S. Richards
L. V. Steck

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FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

TESTING AND EVALUATING CHEMICAL FIRE RETARDANTS IN THE LABORATORY

By

D. L. Dibble, S. S. Richards, and L. V. Steck

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Miscellaneous Paper No. 59 August 1961

U. S. Department of Agriculture, Forest Service
Pacific Southwest Forest and Range Experiment Station
Berkeley, California

TESTING AND EVALUATING CHEMICAL FIRE RETARDANTS IN THE LABORATORY

By

D. L. Dibble, S. S. Richards, and L. V. Steck

Western fire-control agencies dropped seven million gallons of fire retardant mixtures from aircraft in 1960. They are continuing aircraft drops in 1961 and are testing both retardants and suppressants in fire trucks (Davis, Dibble, and Phillips, 1961). It is not surprising that firefighters have expressed considerable interest in learning how new materials are selected for trial on actual fires. This paper describes the first steps in the process of seeking new or improved materials for use in forest fire control and the laboratory methods used in this preliminary screening. Subsequent steps include small scale field trials on forest and range fuels and then operational tests on wildfires (Miller and Wilson, 1957; Phillips, 1961).

Before any new material can be tested by field or operational trials, a great amount of factual information is required. For example, those in charge of forest firefighting will need to know if ample supplies are readily available, what the material will cost, whether special techniques will be needed in mixing, handling, and storage, and if the mixture could damage equipment or endanger personnel (Miller and Phillips, 1958). Firefighters will also want specific answers to such questions as:

1. Are high temperatures or other chemicals required to obtain applicable mixtures?
2. What is the effect on the retardant mixture of the acidity or alkalinity and hardness of the water to be used?
3. Does the material adhere well to fuels when first applied?
4. Does the coating tend to crack or crumble under extreme drying conditions?
5. Is the material sufficiently slippery to constitute a hazard to personnel working around a fire truck or aircraft?

Much of this information may be obtained from brochures of suppliers or through correspondence with the manufacturer. For some of the questions, however, specific answers must be obtained by laboratory evaluation which permits direct comparisons of different materials.

PHYSICAL AND CHEMICAL PROPERTIES

MIXING

Simple tests will show whether the product is readily soluble in hot or cold water and if it requires mixing by rapid agitation or with injector-type mixers. The effect of the acidity or alkalinity and the hardness of the water used on the resulting mixture can be observed at the same time. When available, the manufacturer's recommendations are very helpful in determining the best method of making a solution of the proper viscosity. A sample of the mixture is placed in a beaker and its viscosity recorded at room temperature with a Brookfield viscometer (fig. 1).

STABILITY

Fire retardants often have to be mixed and stored in advance of anticipated use by initial attack aircraft or by ground tankers. To determine stability of stored mixtures, a beaker sample is placed in an oven maintained at 80° F., and viscosity is measured after 24, 48, 168, and 720 hours. The mixture is checked to see if the retardant has tended to separate or has remained in solution, if evaporation has been excessive or if bacteria have caused spoilage. To prevent spoilage, a preservative may have to be added to the mixture.

CORROSIVENESS

The corrosive action of a fire retardant on metal parts of fire equipment, such as hose connections, pumps, and storage facilities may definitely restrict its use. The increased use of air-tankers

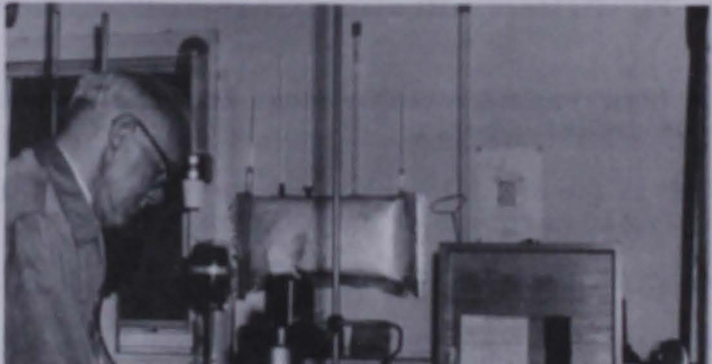

Figure 1. —Using a viscometer to determine the thickness or viscosity of a potentially new fire retardant.

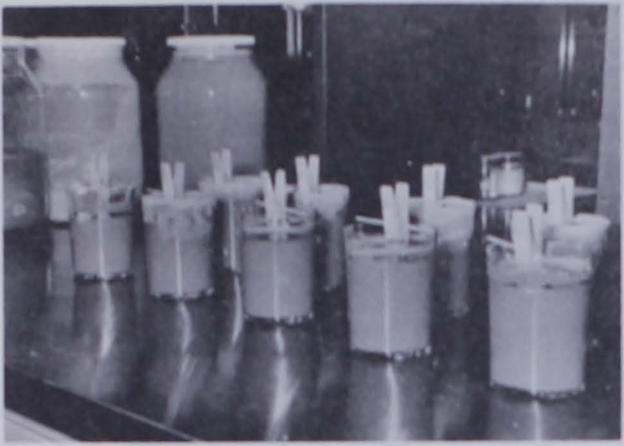

Figure 2. —Metal strips are submerged in samples of a retardant solution during the static test.

on forest fires makes it doubly important that corrosive effects of retardants on aircraft parts be known and eliminated, because of the danger to operating personnel and the high upkeep costs of the aircraft. Therefore, suggested retardants are subjected to two types of corrosion tests.

One type is a "static" test, conducted according to the method outlined in Chemical Engineering Handbook (Perry, 1950). Pieces of the metals commonly used in firefighting equipment are totally submerged in the test solution for 120 hours (fig. 2) and weighed to determine losses due to corrosion.

The metals used in these tests are: (1) copper, (2) brass, (3) bronze, (4) mild steel, (5) aluminum, and (6) magnesium. Test samples 0.025 inch to 0.075 inch thick are cut into 1- by 2-inch rectangles before submersion; they are lightly polished on a buffing wheel to remove scratches and tool marks, washed in a solvent to remove any oil film, and dried. The retardant to be tested is placed in 250 cc. beakers and allowed to stabilize for 1 hour at room temperature. A sample of each test metal is then placed in a beaker with the retardant for five days (fig. 2). Each test piece is weighed to the nearest 0.1 milligram on a precision balance before and after the test. The weight loss is calculated in milligrams per square decimeter per day (mdd).

The second type of test simulates field conditions in which the metals are not only exposed to the chemicals, but to the air as well, or alternately exposed to chemical and air. Materials for this "dynamic" test are prepared as for the static test, but the test pieces are suspended from a shaft rotating at one r.p.m., so that the pieces are alternately submerged and then exposed to the air for about 30 seconds (fig. 3). This cycle is continued for 72 hours. In both the dynamic and static procedures each test is repeated from 2 to 5 times.

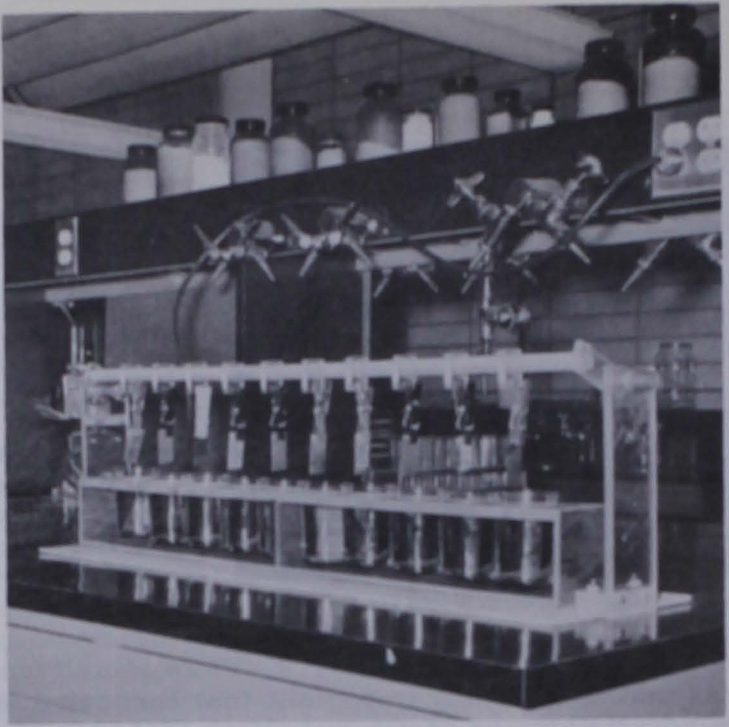

Figure 3. —Metal strips are alternately immersed in the retardant and exposed to the air during the dynamic corrosion test.

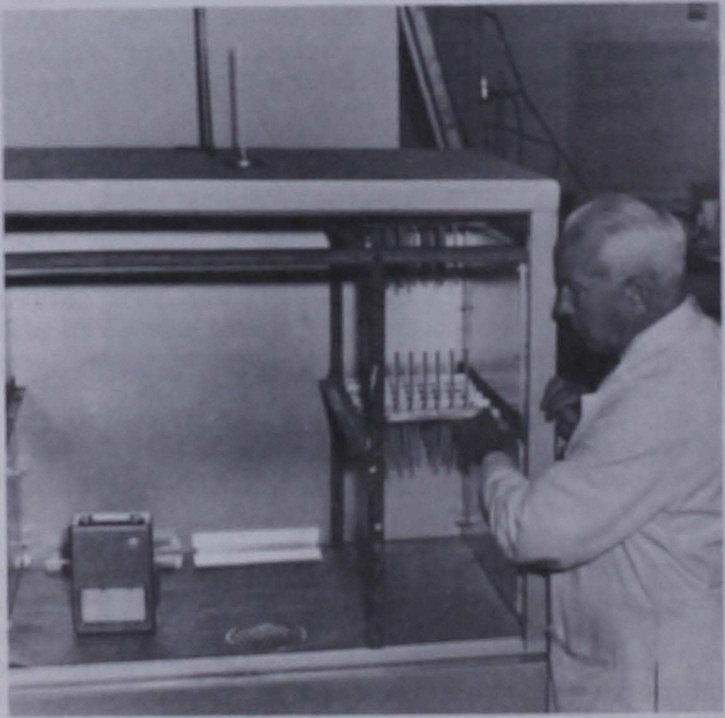

Figure 4. —Drying test dowels in an oven to simulate sun and wind conditions near the fireline.

FIRE RETARDANT EFFECTIVENESS

Three test procedures are used to evaluate fire retardant effectiveness. Two of these tests are relatively simple procedures used to measure resistance to ignition and reduction in combustion rate. The third, called the "steady-state fire model technique," is somewhat more time-consuming, but more nearly simulates fire spread through vegetation. It is usually reserved for those materials showing the most promise in ignition and combustion tests. It should be emphasized that these tests are part of a screening process. They make it possible to determine which materials should be evaluated in the field, but they are not a substitute for field evaluation.

IGNITION TESTS

Resistance to ignition is determined by measuring the time required for treated and untreated maple dowels to burst into flame when placed in a muffle furnace (Phillips and Miller, 1959). Sixty-four maple dowels, 1/4 inch in diameter by 5 1/2 inches in length, are prepared for a single test. Eight of them are sawed into 1/4-inch lengths for fuel moisture determination by the xylene distillation method. One set of 6 dowels is reserved as control samples. Five sets of 10 each are used for ignition tests.

All six sets are clamped upright into aluminum holders, placed in a Napco Mod. E 7162 drying oven (fig. 4) and held in circulating air at 115° F. for 24 hours. After drying, the control set is weighed, all sets are dipped 5 inches deep in the retardant to be tested, and the control set is again weighed. All six sets are then placed in the drying oven. The time is recorded. At the end of one hour, the control set is again weighed and returned to the oven, and a set of 10 dowels is removed for the ignition test. This procedure is repeated at hourly intervals through five hours.

For the ignition test, the dowels are placed, one at a time, in a holder and inserted in the muffle furnace (fig. 5). The time until a burst of flame indicates ignition is measured by a stop watch, and ignition time for the ten dowels is averaged.

The control set is kept in the drying oven 24 hours and then weighed. This set provides a record of the amount of retardant and water adhering to the fuel, the water loss each hour for 5 hours, and the amount of retardant adhering to each dowel after 24 hours drying.

This same test may be made with plain, untreated dowels and with dowels dipped in water as a basis for future comparisons if required. The test may also be made for different furnace temperatures, usually from 1,000° to 1,700° F. at 100° intervals.

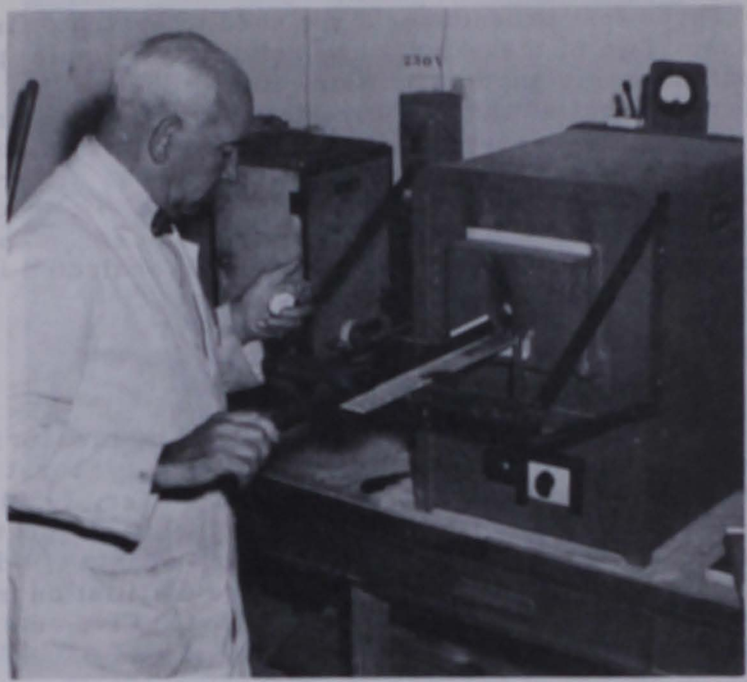

Figure 5. —Determining ignition time for test dowel with an electric muffle furnace.

COMBUSTION TEST

The ability of a retardant to slow or inhibit combustion is determined by burning treated dowels and recording the resulting radiation intensity and weight loss.

Weight loss is measured with a 5-kilogram laboratory scale (Toledo-Model 4030). The scale is equipped with an aluminum frame clamped to the side of the main platform of the scale (Von Kleeck and Tyner, 1937). This frame supports a horizontal slotted metal strip from which the test dowels are hung with 1/2-inch intervening air space between each. A pan beneath the dowels collects falling ash or charcoal. A Gier and Dunkle radiometer is placed 9 feet horizontal distance from the fire, and the radiation intensity recorded by means of a recording potentiometer (G-E type 8CE5).

Each test requires four untreated and three retardant-treated 1/2-inch diameter by 7.5-inch long ponderosa pine dowels. The untreated dowels produce the heat required to burn the three treated ones with which they alternate on the slotted strip. Each dowel is hung by a small wire brad driven into one end.

Forty-one dowels are needed to test each retardant mixture. They are conditioned 24 hours in the drying oven to approach equilibrium moisture content. Six dowels in a special holder are used as a weight control. The tare weight of the holder is determined, as is the weight of the six dowels. These dowels, together with five other sets of three each, are then dipped in the retardant to be tested, and the weight of the control set is again recorded. All are then replaced in the oven for drying. At the end of each hour of drying time, the special holder of six is weighed to determine the water loss, and three treated dowels are removed from the oven and suspended from the scale in positions 2, 4, and 6 on the slotted strip of metal. Four untreated dowels are hung in the 1, 3, 5, and 7 positions.

A horizontal asbestos wick containing 6.7 cc. of ethyl alcohol directly below the dowels is ignited and at the same time the weight is recorded from the scale, and a stop watch is activated. Every 30 seconds the scale reading is recorded (fig. 6). These readings show the loss of fuel weight owing to combustion, while the chart connected to the radiometer registers the radiant heat produced by the combustion.

These records will show the comparative effectiveness of various retardants; some may slow down the combustion process in the treated dowels; others may prevent combustion. The test is repeated at hourly intervals to show the ability of a retardant to remain effective after different drying periods.

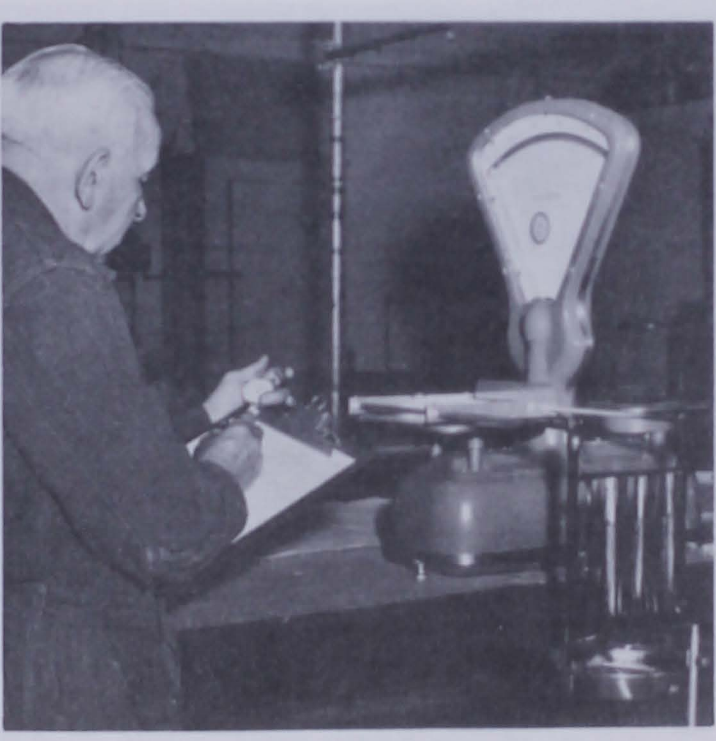

Figure 6. —Combustion test dowels suspended from a balance to determine the rate at which they lose weight.

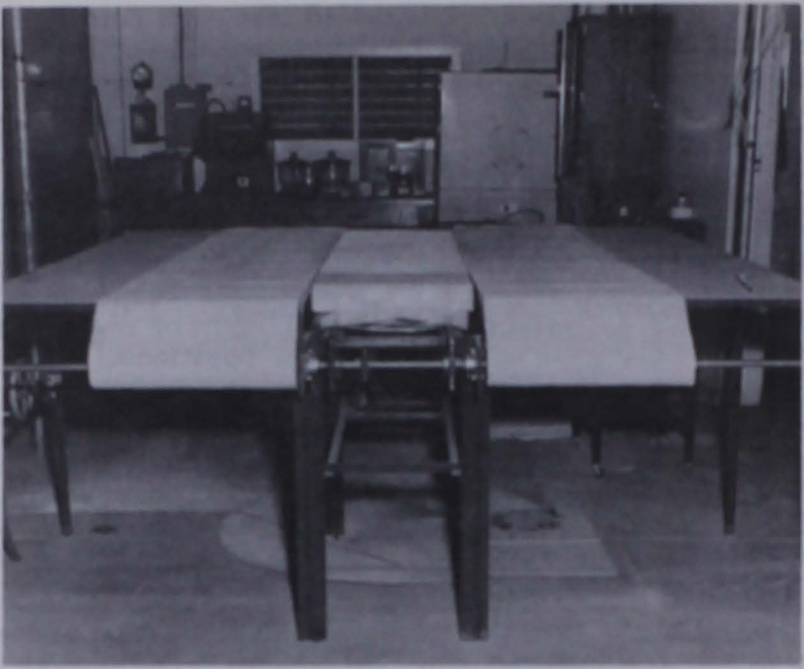

Figure 7. —Fire table used to determine rate of spread and burning intensity.

STEADY-STATE TECHNIQUE

In the steady-state test the rate of spread, the radiant energy, and the convective heat of a fire burning in an untreated portion of a crib of 1/2-inch dowels are compared with measurements obtained when the fire burns into the retardant-treated portion of the same crib.

The fire table (fig. 7) and other equipment used in this test was developed in fire model studies conducted at the Richmond Laboratory [1] (Fons et al, 1960).

The fuel for this test consists of a crib built of 6 tiers of 21 dowels 7.5 inches long and 6 tiers of 5 dowels 35.5 inches long. These dowels are 1/2-inch-round ponderosa pine. They are placed in a jig, glued with small drops of resin adhesive, kept under pressure overnight, and subsequently conditioned in the drying oven for 24 hours at 115° F.

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[1] Office of Civil and Defense Mobilization Contract No. D CM-SR-59-10, and U.S. Forest Service Contract No. 12-11-005-20170, dated October 27, 1958.

The crib is removed from the oven and weighed. One end is dipped 12 inches deep into the retardant to be tested and allowed to drain for 5 minutes. It is again weighed to determine the amount of retardant and water adhering, and replaced in the oven for a specified time (1 to 24 hours). It is then weighed again and placed on the movable center strip of the fire table.

The untreated end (in line with the eyes of the operator) is ignited with an asbestos wick containing 6.7 cc. of ethyl alcohol. As the crib is consumed, the operator cranks the fire "front" forward to keep it in a steady position before him, recording the number of revolutions he has turned the crank each minute (fig. 8). A Gier and Dunkle radiometer aimed at the fire and mounted at a horizontal distance of 14 feet, records the radiant energy on a recording potentiometer. The 2 feet of untreated fuel bed gives the fire a chance to reach a "steady state" before reaching the retardant. After this, the drop in intensity and rate of spread, as graphically represented on the recorder charts, forms a basis for comparison between retardants.

In all tests using wood dowels or cribs, the moisture content of forest fuels is determined by xylene distillation and the results are considered in the analysis of the results.

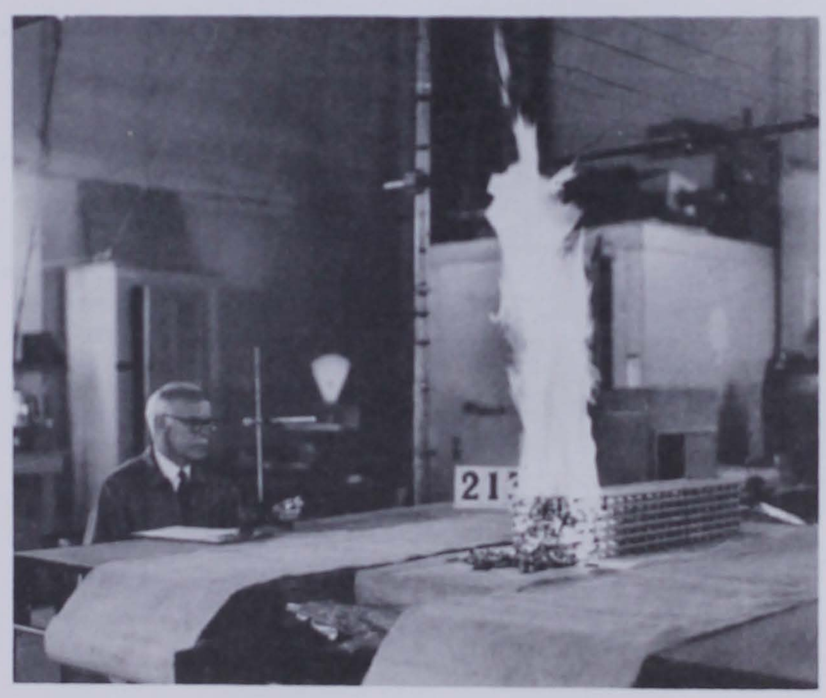

Figure 8. —"Steady-state" fire burning in a crib on the fire table. The last 12 inches of the crib have been treated with retardant.

CONCLUSION

After a new chemical fire retardant makes its debut, it has a long way to go before it can be accepted as a full-fledged usable retardant. It is subjected to laboratory, field, and operational tests and is examined from many different angles. Of more than 50 retardants and retardant combinations tested in recent years, only two have taken their place in the fireline, and two others have reached the operational testing state.

Laboratory testing and evaluation of chemical fire retardants is not basic research in chemistry or fire physics. The tests are merely tailormade comparisons of existing and new retardants. Furthermore, laboratory tests are not the final answer. Since it is not practical to field test all suggested retardants, laboratory tests answer the question: "Does the new retardant show enough promise to justify field testing?" Laboratory tests take time and effort. They are done by our limited staff along with other major fire research responsibilities. We are not, therefore, able to test immediately every chemical that comes into the laboratory.

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MISCELLANEOUS PAPER No. 60
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GUIDELINES FOR ESTIMATING THE SURVIVAL OF FIRE-DAMAGED TREES IN CALIFORNIA

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BERKELEY, CALIFORNIA

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Wagener, Willis W.
1961. Guidelines for estimating the survival of fire-damaged trees in California. U.S. Forest Serv. Pacific Southwest Forest and Range Expt. Sta. Misc. Paper 60. 11 pp.

Survival of conifers after fire damage depends on time of year when the fire occurred, the growth vigor of the damaged tree before the fire, and degree of damage to cambium, foliage, and twigs. Guides by tree species or species groups are given for judging survival chances of individual damaged trees.

GUIDELINES FOR ESTIMATING THE SURVIVAL OF FIRE-DAMAGED TREES IN CALIFORNIA[1]

By Willis W. Wagener, Forest Pathologist
Division of Forest Disease Research

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Miscellaneous Paper 60 September 1961

U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
Berkeley, California

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[1] This paper revises and replaces "Preliminary guidelines for estimating the survival of fire-damaged trees," Research Note No. 98, October 4, 1955.

GUIDELINES FOR ESTIMATING THE SURVIVAL OF FIRE-DAMAGED TREES IN CALIFORNIA

By Willis W. Wagener

When virgin timber was plentiful in the West, stands swept by fire were considered lost. As old-growth was harvested and timber values increased, salvage logging after fires gradually became a common practice, and establishment of a new forest by planting or seeding burns received increasing attention. Today, rehabilitation of a burn ranks with or above salvage in importance.

In rehabilitating burns, foresters recognize the need to take advantage of the natural capacity of trees to recover from fire damage. Where few trees escape heavy damage and planting is scheduled, clear cutting in salvage operations is often advisable. Clear cutting permits more efficient planting and more thorough site preparation. In large burns planting cannot be scheduled immediately, and leaving trees that would survive offers a chance for natural regeneration and gains in time, quality, and seed source. To capitalize on this chance, foresters need to understand a tree's survival potentials after fire and how to judge them.

In 1939, following early work by forest entomologists (Miller and Patterson, 1927; Miller, 1929; Salman, 1934; Miller and Keen, 1960), the Office of Forest Pathology [2] began a study in California of the survival of fire-damaged ponderosa and Jeffrey pines. The study was originally confined to these two pine species because of their high intrinsic value and the prevalence of misconceptions regarding their survival chances following fire. Later it was extended to other conifers.

Sample damaged trees were selected on fresh burns and their condition recorded. Reexaminations were made annually until mortality had returned to normal, usually within 3 to 4 years. Observations on 30 burns located on 12 national forests in California and in Yosemite National Park provide the basis for generalizations presented here as guidelines. Part of what follows is in the nature of background to aid in the understanding of the criteria for survival.

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[2] Formerly in the Bureau of Plant Industry, Soils and Agricultural Engineering, U.S. Department of Agriculture; now in the Division of Forest Disease Research, Pacific Southwest Forest and Range Experiment Station.

Influence of Fire Date on Survival

Conifers are most susceptible to fire damage early in the growing season, when length growth of the main stem and of twigs is active. This growth is chiefly from food reserves stored during the previous season. Such reserves are at their lowest during the period of length growth. Also, during this time, growing points are tender and easily killed by heat. The length-growth period varies in timing with elevation, species, and duration of snow cover but in California is likely to be at a maximum in June (Fowells, 1941).

After length growth ceases, the terminal buds form and, in pine species such as ponderosa and Jeffrey, become well protected by scales by the end of summer. In this stage the buds are able to withstand considerable heat without serious damage. Diameter growth on the tree, which proceeds largely from food currently elaborated by the foliage, stops in late summer, but food reserves continue to accumulate during the balance of the season. Thus the later the fire the better the tree is prepared to withstand fire damage. In an early-season fire, a conifer is highly vulnerable to heat damage at a time when the tree must retain sufficient green foliage to carry it through the remaining part of the growing season and provide some food reserves for the next year.

The time of year at which the fire occurs also affects subsequent bark beetle activity, which can materially influence survival. According to Miller and Keen (1960) "if a fire occurs in the late spring or early summer, some concentration of infestations within a burn develops by late fall of the same year." After late summer or fall fires, however, "beetles do not concentrate within a burn until the season following the fire." Our records support these conclusions. Any scattered attacks that may occur after a late-season fire are likely to be confined to mortally-damaged trees with mostly live cambium but with little prospect for survival.

Survival in Relation to Growth Rate and Site

The survival chances of a scorched conifer are strongly influenced by the condition of the tree before the fire. Young, fast-growing trees on good sites have the best chance, and old, overmature veterans on poor sites the poorest chance to recover from fire damage. Fire-injured trees of any age that were making slow growth before a fire will have a low recovery potential afterward. On the other hand, vigorous young ponderosa pines on good sites occasionally survive 100 percent heat-killing of foliage in a late-season fire if most of the buds and twigs remain alive. Even on good sites, old, overmature, slow-growing trees are poor risks to live after a fire if damage is at all severe.

Survival in Relation to Tree Damage

Bud and twig kill, foliage kill, and bark and cambium kill, all need to be considered in judging whether a tree is likely to live after a fire injury. In past marking on burns, the tendency has been to base judgments too much on the amount of green foliage remaining, without sufficient attention to other factors influencing survival. Actually, as Miller (1929) has pointed out, it is the total growth capacity of the tree for the year or two after a fire that largely determines a scorched tree's fate.

Crown Damage

Except for very early-season fires, the crown condition the year following the fire is more important for survival than the condition shortly after the blaze. In ponderosa and Jeffrey pines extensive heat-killing of foliage may sometimes occur with only light damage to buds and twigs. During the succeeding months most of the dead foliage will be shed from twigs that are still alive; a new crop of needles will be put out from them the next growing season. Thus the amount of green crown the year after a fire may be much greater than that a month after in these pines. The new foliage on a defoliated part of the crown is not quite the equivalent of uninjured crown because it bears only current year's needles, but these help greatly in keeping the tree alive until a normal needle complement is attained.

In species with slender twigs and small terminal buds, as in sugar pine, Douglas-fir, and the true firs, or in those without definite terminal buds, as in incense-cedar and giant sequoia, foliage kill and bud and twig kill from fire are not greatly different in amount. Thus, the amount of green foliage present in scorched crowns in these species shortly after a fire is reasonably close to the amount that will be present in the immediately following years.

Damage to Bark and Cambium

Miller (1929) and Salman (1934) each observed that pines with both heavy foliage scorching and moderate to severe cambium kill as a result of fire were more likely to die later from bark beetle attack than pines with only one of these types of injury. Where both types of injury are present, food materials available for repair of the damage are sometimes insufficient to be fully effective.

Conifer bark varies greatly between species in insulating capacity and in other characteristics that influence the protection afforded to the cambium against heat injury. Even in a single species, wide differences in bark thickness, depth of crevices, and size of bark ridges or plates influence the amount of stem damage. Damage is also influenced by the amount and distribution of forest fuels—ground cover, litter, duff, and debris near or on the ground. Thus in uneven-aged stands of mixed species swept by fire, injury to the cambium is likely to show considerable variation in locations where tree killing is not complete.

Cambium killing that extends up the trunk for more than a few feet has a greater influence in reducing chances for survival than injury close to the ground. Inner bark injury from heat high on the stem where the bark is thin is particularly likely to result in later mortality. Injury of this character sometimes occurs adjacent to areas of localized crowning of the fire.

Sugar pine constitutes a special case. In proportion to diameter, sugar pine has thinner, denser bark, with poorer insulating capacity than the bark of associated conifers. During a fire, the burning of fuel accumulations at ground level often kills a ring of cambium only a few inches in height around part or much of the base of sugar pines, even where the bark shows only minor scorching on the surface above this level. Larger sugar pines can occasionally be found with inconsequential needle scorching and little blackening of the trunks but more than half girdled at ground level by a narrow band of killed cambium. To offset this greater susceptibility to basal cambium killing than in associated conifers, sugar pine withstands the effects of partial girdling much better than associated species.

Bark Beetles and Survival

Fire-damaged trees are weakened physiologically, and for two or more years are more attractive to bark beetles than normal trees (Miller and Keen, 1960). Trees with a good survival potential often adjoin others with little or no survival prospects but with enough green cambium and live twigs to attract bark beetles. If salvage logging in such situations is delayed too long, bark beetle broods emerging from heavily damaged trees will be likely to attack neighboring trees that would otherwise survive.

According to observations during the study, beetle attacks and spread are particularly likely in young-growth ponderosa pine stands swept by a relatively hot ground fire. Such stands yield little lumber of upper grades and loggers have the tendency to leave them until the last in salvage operations. By this time the bark beetle population often is high, and many trees that would otherwise have survived have been attacked and killed.

The remedy is obvious: logging should be adjusted to salvage such stands before beetle infestation has pyramided, preferably by at least midsummer of the year after the fire, taking out all infested trees in the process. Only in this way can the real survival potential of the stand be realized. There will also be less sapstain in the salvaged trees than when logging is delayed.

The pinkish or reddish pitch tubes of the red turpentine beetle, Dendroctonus valens Lec., were noted on the bases of 30 percent of the pines included in the study, mostly within a year after the fire. Where not numerous, the beetle work evidenced by their presence seemed to have no apparent effect on the survival of affected trees.

Seed Production from Damaged Trees

Attention should not be focused exclusively on salvage or survival in the marking of fire-scorched timber. A fresh burn provides an excellent seedbed and seed produced by scorched trees is sometimes highly important in regenerating a burn.

Before marking is started in parts of a burn where the fire has not crowned, the cone status on the pines should be investigated, particularly with respect to the juvenile cone crop that will mature the following year. Exceedingly good stands of seedlings sometimes result from these cones, even though the trees bearing them may not live beyond the second year after the fire. The prospects of a good seed crop will sometimes justify the temporary retention of trees that would otherwise be marked for initial salvage, or that would normally be cut under certain silvical concepts such as unit area control.

The production of a heavy cone crop draws on nutrients that would otherwise aid in recovery of the parent tree, and makes it more susceptible to subsequent loss than equally damaged trees without a cone crop. Thus trees with a heavy cone crop may die the second year after the fire. However, they can still be salvaged after the seed crop has been obtained.

Judging Fire Injury

In Crowns

Where the fire has crowned or has been so intense that no green foliage is left, marking offers no problem and can proceed at once. Salvage logging in such timber should start as soon as possible to avoid deterioration.

Where some green foliage is left and pines with relatively large buds and twigs, such as ponderosa and Jeffrey pines, are major stand components, marking should be delayed for two or more months if possible. It should not be done in the fall if the timber will not be logged until the next spring. By spring most of the scorched needles will be shed from twigs that are still alive but not from dead twigs. Thus live parts of the crown will appear thin in contrast to the dead parts, allowing the marker to tell easily how much live crown is present to produce green needles when growth starts. The amount of live crown present, as distinguished from green foliage, is the most important single factor in the survival of fire-scorched ponderosa and Jeffrey pines.

For preliminary estimates, or where prompt marking is unavoidable in parts of burns where killing is not complete, the following suggestions are offered:

(a) Mark or estimate only on clear days. Green parts of partially scorched foliage are extremely hard to see against a cloudy sky.

(b) Wherever possible, view crowns from the side on which the sun is shining and at right angles to the direction of run of the fire. The lee side of the crown usually is the least damaged.

(c) Use field glasses to check naked-eye impressions. Green needle bases that indicate that surrounding parts of the crown are still alive can often be seen with the aid of field glasses but are not distinguishable with the naked eye.

(d) Watch the position of foliage. Twigs bearing darkened needles that are "frozen" in position in the direction of run of the fire are certain to be dead. Heat-killed foliage on live twigs stands or hangs in a normal position. The presence of such foliage does not always signify live twigs, but it is a hopeful indication that they may be alive.

(e) Anticipate less difference between the percent of live crown and the percent of green foliage after a midseason than after a late-season fire.

In Bark and Cambium

Cambium injury is ordinarily heaviest on the lee side of the tree with respect to the direction of run of the fire and on the uphill side of trees located on slopes. Killed patches of cambium are usually widest just above ground level and taper upward.

The degree and location of bark charring provides some indication of where to look for cambium injury, but for each area the relationship should be checked by exploratory sampling through the bark with an axe. Enough trees should be sampled to provide for reasonably accurate judgments regarding cambium injury on the rest. In most species, killed inner bark or cambium is readily recognized by a change in color to some shade of brown or gray and by resin infiltration of the wood in the cambial region. In white and red fir, however, no appreciable color change accompanies injury to the inner bark and cambium, no resin infiltration is induced, and the limits of cambium killing are difficult to judge.

The most common form of injury to cambium or inner bark is narrow strip killing or browning underneath deep bark crevices on the lee side of the tree. Ordinarily it has little influence on survival.

Basal patch killing of cambium involving less than one-sixth of the circumference of the tree at the ground and extending up for not more than a foot is also usually of minor significance for survival. A third type of cambium injury commonly found on burns is the death of thinly protected callus tissue around the borders of old fire wounds or catfaces. This killing likewise seems not to have much influence on the survival chances of a tree unless it extends beyond the callus zone and forms a broad band of killed cambium.

Scattered resin drops over the charred bark of lower trunks are usually not significant as indicators of cambium injury. Scattered drops come chiefly from dead branch stubs or the bases of lower branches and not from the bark of the trunk itself. Concentrated resin flow from specific areas of bark or exposed wood, on the other hand, does indicate killed cambium underneath. The flow usually issues from calluses around previous fire wounds, from old dwarfmistletoe cankers on the trunk, or from irregularities in normal trunk contours from other causes. It is also common where large chunks of fallen logs have burned close to the bases of trees.

Survival Criteria

Most timber fires in California occur after the first of August, most sites burned over are relatively good, and the trees with the best chance for survival are those with good growth vigor before the fire. Marking criteria for trees falling within these specifications are given in table 1, together with modifications for certain other conditions. Trees not meeting the criteria, such as pines with less than 50 percent of live crown, slow-growing trees, or those with severe cambium injury, should ordinarily be cut unless reserved only temporarily.

No criteria are given for early-season fires because of lack of data; no early-season fires were included in the study. From general considerations, however, it is believed that reserved trees from an early-season fire should have 35 percent or more of green foliage.

Variable percentage criteria are given for midseason (July) fires to permit adjustment to the conditions on a particular burn. The growth and developmental status of a tree changes rapidly during July, seasons differ in being late or early, and trees at low elevations start growth much earlier than those at higher elevations (Fowells, 1941). Accordingly, no one criterion is likely to fit all July burns. In general, trees on an early July burn require more green foliage for survival than trees on a late July burn.

The studies did not include any areas under severe drought stress so they provided no information on how drought might affect fire survival. Chances are, however, that no more green crown would be needed for survival under drought conditions than when moisture was normal. Fires reduce the competition for soil moisture and by killing some foliage, reduce moisture needs of individual trees. Thus the moisture supply to the living parts of a tree after a fire in a drought area may actually be better than before the fire.

Definition of Terms

Fire period:

Early season—Fires occurring before July 1.
Midseason—Fires occurring during July.
Late season—Fires occurring after August 1.

Cambium injury:

Light—Confined to injuries characterized in the section on "Judging Fire Injury" as having little effect on survival.

Moderate—On species other than sugar pine, cambium killing involving less than 25 percent of the circumference and not extending above stump height, except for narrow strip kill under a few bark crevices. On sugar pine moderate injury includes basal cambium killing at ground level involving not more than 60 percent of the circumference.

Severe—Cambium injury in excess of that described under the above classes.

Live crown:

The proportion of the original live crown in which twigs and buds are still alive after the fire, including parts bearing green or partly green foliage. Often irregularly dispersed. Estimated to the nearest 5 percent.

Green foliage:

The proportion of green needles present after the fire without respect to location within the former crown, compared with the green needle complement before the fire. Includes the green part of partly-scorched needles. Estimated in percent as closely as possible.

Table 1. —Criteria for survival marking of fire-scorched timber in California

Influencing factors	Minimum criteria for survival of—					
	Ponderosa pine Jeffrey pine			Sugar pine Douglas-fir[1] White fir Red fir Incense-cedar Giant sequoia		
	Cambium injury	Live crown	Green foliage	Cambium injury[2]	Live crown	Green foliage
General specifications		---Percent---			---Percent---	
Fire period—late season Site quality—above average Growth vigor of tree before fire—good	None or light	50 or more	10 or more[3]	None to moderate	45 or more	35 or more
Modifications						
In cambium injury—general specifications as above	Moderate	50 or more	20 or more	--	--	--
In site—below average, Sierra East Side and West Side, other general specifications unchanged	None or light	50 or more	15 or more	None to moderate	50 or more	40 or more
In fire period—midseason other general specifications unchanged	None or light	50 or more	15 to 25 or more	None to moderate	50 or more	40 to 50 or more
In growth vigor—crown small, vigor moderate, other general specifications unchanged	None or light	60 or more	15 or more	None to moderate	55 or more	45 or more

[1] Does not include bigcone Douglas-fir. In this species the percent of live crown is not readily determinable; green foliage should be 20 percent or more.

[2] In sugar pine, includes up to 60 percent basal girdling.

[3] Not an actual green foliage minimum for survival. Seventy percent of the pines in the study with 50 percent or more of live crown but with less than 10 percent of green foliage survived.

Estimating, Marking, and Logging on Burns

On parts of burns where the fire did not crown and killing is not complete, early estimates of loss or salvage should be applied with ample provision for later adjustment after survival prospects have become more definite.

Marking in such timber is best done with a two-man crew, one to examine crowns from a distance and the other to appraise for cambium kill and apply the marking symbols.

To obtain maximum salvage, survival, and seed crops on burns, two-stage logging is advisable. The survival of seriously damaged trees is in part a matter of chance, depending on weather conditions, bark beetle activity, and actual bark and cambium injury as compared with the estimated injury. The first round of logging should be confined to pines completely killed or with little chance for survival and in which sapstain is likely to affect the value of the product. Associated species such as the firs and incense-cedar, in which sapstain is ordinarily not a major consideration, should be left for a second round. At this time the logger can also take out any dying or beetle-attacked pines that have shown up among those reserved in the first round.

Two-stage logging has several advantages. It permits a more rapid coverage of a burn than would be possible if everything were taken on a single round. It reduces the chances for deterioration in the part of the timber most subject to degrade from stain and borers. It also tends to hold down bark beetle activity.

Discussion

From what has been presented, it should be clear that handling burns for maximum survival and natural seeding requires flexibility in practice and thinking. One general practice has been to mark an entire burn as soon and as rapidly as possible, even though the salvage logging may span many months. If tree killing was complete, this practice has much to commend it. In those parts of the burn where killing is not complete, it practically guarantees poor marking for survival. Incomplete kill is most likely in backfired areas or where the fire burned downhill at night. If marking in such areas is delayed until the timber is actually needed in logging, a very much better job of saving trees with a good survival potential is possible.

Saved trees may permit more effective use of limited planting funds. Improved methods have led to good planting success in California in recent years, but planting is still expensive. It may be necessary to concentrate planting on ground where kill has been complete and there is little possibility of natural reseeding. The temporary retention of living trees to mature a seed crop and the protection during logging of seedlings established on a burn the first season after a fire (Roy, 1956) are measures which deserve consideration.

Another common practice has been to leave the plan of logging in a salvage operation entirely up to the logger, who usually starts at the most accessible part of the burn and works through. On small burns, where the entire salvage job will be completed in two or three months, this method of operation is as good as any. On larger burns, however, the plan of logging needs to be adjusted to the condition of the timber if the most is to be accomplished with the least loss. On very large burns, especially under mixed ownerships, the prospects for adjusting logging to reduce losses are usually less favorable than on smaller burns, but this does not mean that in such cases nothing should be attempted. Cooperation can often be obtained if the people concerned understand the objective: to save for the future all the trees that can be saved.

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MISCELLANEOUS PAPER No. 61
OCTOBER 1961

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FITTING BRUSH CONVERSION TO SAN GABRIEL WATERSHEDS

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FOREST AND RANGE
EXPERIMENT STATION
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FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

ACKNOWLEDGMENTS

The San Dimas Experimental Forest is maintained by the Forest Service, U.S. Department of Agriculture in cooperation with the California Division of Forestry. Since 1947 this has been a joint research project with the California Division of Forestry, which participates in program planning and provides financial support. Other long-term cooperators are the Los Angeles County Flood Control District, the Los Angeles County Fire Department, and the University of California, which provide staff or other support or use research facilities at the experimental forest.

Special recognition is due these agencies and the California Department of Water Resources for assistance with emergency rehabilitation work after a wildfire in July 1960. Their cooperation made it possible to restore experimental facilities and start emergency research on methods of managing chaparral watersheds for more effective control of fires, floods and erosion, and water yield.

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FITTING BRUSH CONVERSION TO SAN GABRIEL WATERSHEDS

By Jay R. Bentley

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Miscellaneous Paper No. 61 October 1961

U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
Berkeley, California

FITTING BRUSH CONVERSION TO SAN GABRIEL WATERSHEDS

By Jay R. Bentley

The coastal slopes of the San Gabriel mountains in southern California are wildlands on which intensive management is justified. These watersheds lie directly above heavily populated urban areas and highly developed industrial complexes. An adequate vegetation cover on the watersheds is valued for several reasons—primarily to protect against flood and erosion damage, but also to promote yield of local water and to provide recreation areas and wildlife habitat.

Intensive management requires that some changes be made in the native plant cover—for example, the conversion of brush to a different type of vegetation on selected areas. One purpose of selective brush conversion is to break extensive brushfields into smaller units for more effective control of fires. Under the typically hazardous conditions which prevail most of the year in southern California, fire control is extremely difficult in continuous dense brush. The brushfields can be broken up by establishing fuel-breaks at strategic locations. Fuel-breaks are wide strips of land on which the heavy brush cover is converted to vegetation with lower fuel volume and less resistance to fire control. Reduction of acreage burned by the few large fires which escape initial attack is the aim--and this is the key to reducing floods and erosion.

Selective brush conversion also has other purposes. It can increase water yield by removing excess woody vegetation from canyon bottoms and some slope areas of deep soil (Rowe and Reimann, 1961). Removing hazardous woody fuel from some areas of high recreational value can make them more accessible and protect natural or planted groves of trees from being destroyed by fire. Wildlife habitat will be improved if the brushfields are broken up with areas converted from brush to grass, and new range for livestock, if needed, can be developed on limited favorable sites.

But the watersheds represent extremes in steep terrain and shallow rocky soils. Dry, hot weather prevails much of the year. These physical factors definitely limit the feasibility of converting the native brush to a different vegetation type over large areas. How can brush conversion objectives be fitted to such watersheds?

A look at the results from a soil survey of the San Dimas Experimental Forest, which includes two typical San Gabriel drainages, shows that the choice of areas for conversion will be strongly affected by steepness of slope and depth of soil. More than 80 percent of the experimental forest has steep or extremely steep slopes, and almost 75 percent has shallow or very shallow soils (table 1). These characteristics affect not only the possibilities for changes in cover type but also the practicability of conversion techniques.

Table 1.--Percent of acreage on the San Dimas Experimental Forest, by slope gradient and soil depth classes

Steepness of slope	Dominant depth of soil					All depths
	Very shallow	Shallow	Medium	Deep		
	Under 1 foot	1 to 2 feet	2 to 3 feet	3 to 4 feet	Over 4 feet	
	Percent					
Moderate to steep						
Under 40[1]	--	2	3	1	1	7
40-55	([2])	2	3	1	([2])	7
Steep						
55-70	4	23	12	3	([2])	42
Extremely steep						
Over 70	34	9	1	--	--	44
All gradients	38	36	19	5	2	100

[1] Dominant slope gradient, in percent.
[2] Less than 1 percent of the acreage.

Steepness of Slope

Brush conversion is limited more by slope gradient than by any other physical factor. The most effective and economical methods for each step in the conversion process--removing brush, sowing grass, and killing brush regrowth--involve use of tractors and other ground equipment. On terrain, like that of the experimental forest, tractors can be used on only limited acreage, and much of this acreage is not accessible without expensive road construction. Excessively steep terrain restricts brush conversion methods to aerial applications which are less positive than those using ground equipment, and to hand applications that are extremely slow and costly on slopes too steep for easy foot travel.

In consideration of these limits, steepness of slope on the experimental forest has been mapped in classes (fig. 1):

Moderate to steep slopes.--This class includes all slopes with gradients from 0 to 55 percent, 55 percent being about the maximum on which a heavy tractor can be used. Out of the 17,000 acres within the experimental forest, 14 percent of the land was mapped in this class.

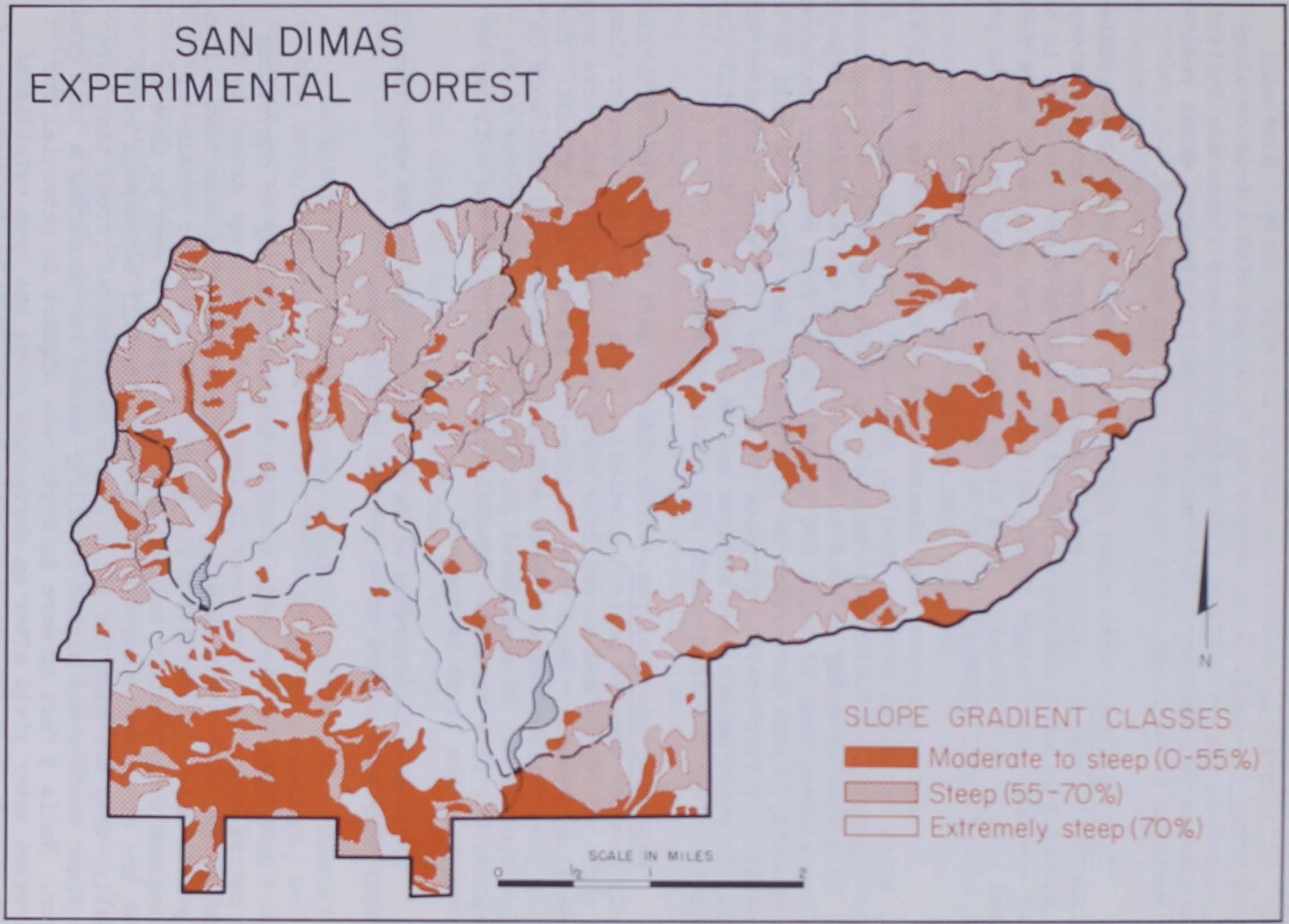
SAN DIMAS
EXPERIMENTAL FOREST
SLOPE GRADIENT CLASSES
Moderate to steep (0-55%)
Steep (55-70%)
Extremely steep (70%)
SCALE IN MILES
0
1/2
1
2
N

Figure 1.--Slope gradient classes on the San Dimas Experimental Forest.

About half of this acreage has slopes under 40 percent gradient, on which bulldozers can be used most safely and efficiently. Some additional areas too small to be mapped can be worked with a tractor along ridges and in canyon bottoms. The moderate to steep slopes are incised with steep-sided drainages that cannot be readily crossed, which reduces the workable acreage and makes tractor operation expensive.

Steep slopes.--This class includes all areas having slope gradients dominantly between 55 percent and 70 percent; these areas are too steep for ground equipment and are difficult to cover on foot. Included in this class are many small slope facets with steeper gradient, which make foot travel even more difficult. This slope class was mapped on about 42 percent of the total acreage.

These steep slopes when cleared must be revegetated by aerial sowing, which has given erratic results, especially on south exposures. Helicopter spraying will eliminate much of the brush regrowth, but the necessary follow-up spraying by hand is time-consuming and expensive, especially on long slopes, many of which are long distances from roads or tractorways. Consequently, brush conversion on this kind of land should be held to that necessary for fire control purposes or to areas from which increased water yield, or other values, are assured and on which the new cover will provide adequate protection from runoff and debris movement.

Extremely steep slopes.--This class is made up of areas with slopes mainly greater than 70 percent gradient. These slopes are steeper than the angle of repose and exceedingly unstable. Loose soil and rocks move downhill by gravity. Hand work is dangerous as well as difficult. The costly job of brush conversion by aerial applications and hand work on such slopes cannot be considered justified or advisable unless it is essential for fire control. Special work to stabilize the soil may be necessary if the brush is removed.

These most unfavorable sites are predominant on the experimental forest; they were mapped on 44 percent of its area.

Depth of Soil

On slopes of favorable gradient the advisability of converting the native brush to a new cover is determined to a large extent by the depth of the soil. For example, coarse-textured soils less than a foot deep rate low in productivity for growth of a new cover because of inadequate soil-moisture holding capacity. Soils 2 feet or more in depth are considered adequate for growth of a full herbaceous cover. Usually, they are also the soils on the experimental forest that have the finer texture and higher fertility needed for producing a full grass cover. Soils 3 feet or more in depth rate highest in potential for increased water yield after an herbaceous cover has been established because in these soils water storage is possible below the use-zone of shallow-rooted plants (Rowe and Reimann, 1961).

Experience and research to date permit broad, relative ratings of the soils of different depth, but their actual productivities for growing grass or yielding water have not been determined. Studies seeking to refine these ratings have been started on the experimental forest (Hopkins, Bentley, and Rice, 1961). Until this information is available, decisions concerning the economic advisability of converting brush to grass must be based on relative ratings of different soil depths.

Three broad classes of soil depth were mapped on the experimental forest (fig. 2):

Medium and deep soils.--Medium depth and deep soils (table 1) are grouped together on the generalized map, but their potentialities are considerably different.

Soils of medium depth (2 to 3 feet) are adequate for production of a good plant cover, but the possibilities for greatly increasing water yield by changing brush to grass on these sites are questionable. However, some increased yield due to greater water storage in the soil during dry seasons can be expected from the spots of deep soil known to occur within areas mapped as medium depth soil, and possibly from spots of deeply weathered parent material below the soil profile itself. Studies are underway to determine whether brush conversion on these medium depth soils is worthwhile for water production alone.

The 2- to 3-foot soils were mapped on 19 percent of the experimental forest acreage. About 6 percent was on slopes under 55 percent gradient where conversion is most feasible and seems justified at present. Almost all of the remaining 13 percent was on slopes of 55-70 percent gradient on which conversion is questionable unless essential for fire control purposes.

For areas of deep soil (more than 3 feet deep) study to date indicates that increase in water yield should be obtained by changing the cover from brush to a shallow-rooted herbaceous cover (Rowe and Reimann, 1961).

Deep soils were mapped on about 7 percent of the experimental forest. Of this, more than half was on slopes under 55 percent gradient, and the remainder on steep slopes where conversion will be difficult and costly.

Shallow soils.--These soils (1 to 2 feet deep) have questionable productivity; on favorable gradient the soil may produce an adequate grass cover. Within the mapped acreage of shallow soils, however, little increase in water yield is expected from removal of the brush. At present, conversion should be restricted to areas on which grass is needed for a specific purpose, such as to break up brushfields for better fire control.

Shallow soils occur extensively, being mapped on 36 percent of the experimental forest. Of this, only 4 percent was on slopes of less than 55 percent gradient.

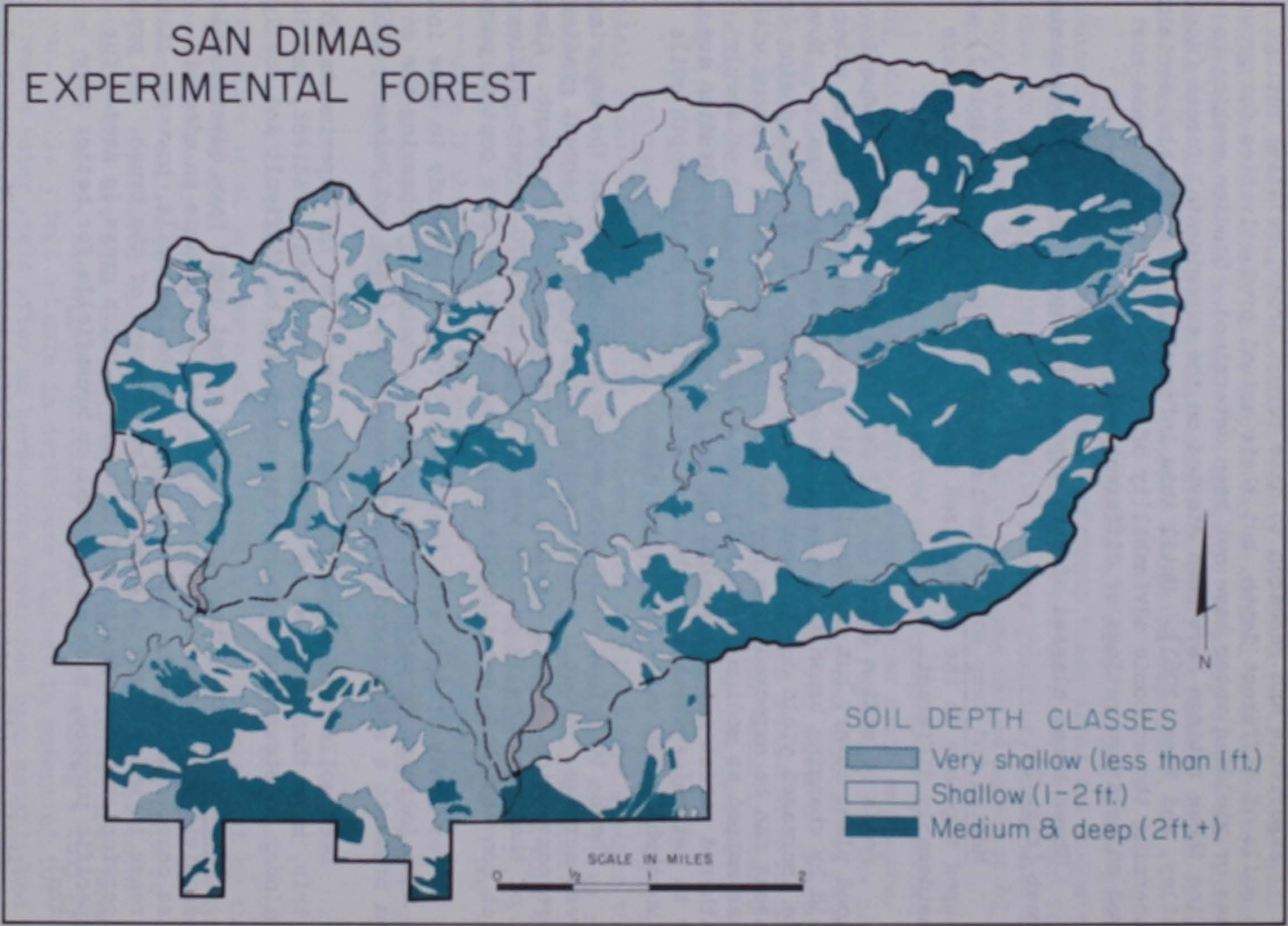
SAN DIMAS
EXPERIMENTAL FOREST
SOIL DEPTH CLASSES
Very shallow (less than 1 ft.)
Shallow (1-2 ft.)
Medium & deep (2 ft.+)
SCALE IN MILES
0
½
1
2
N

Figure 2.--Soil depth classes on the San Dimas Experimental Forest.

Very shallow soils.--Such soils (less than 1 foot deep) are rated low in overall productivity. Brush conversion should be limited to areas on which a lighter cover is essential for fire control.

This too is an extensive soil class; it was mapped on 38 percent of the experimental forest, and 34 percent on slopes greater than 70 percent gradient.

Selecting Brush Conversion Areas

It is plain that only a limited acreage could be called first priority sites for brush conversion aimed strictly at economical improvement in resource values. However, the experimental forest also contains a considerable acreage of questionable suitability on which removal of excess brush may pay in terms of water yield. All of this acreage should be shown on a map before final selection is made of areas to be converted.

First priority sites include the canyon bottoms and the slopes with gradient less than 40 percent and soils more than 2 feet deep. The accesible land of this kind is estimated at about 5 percent of the experimental forest.

An additional 4 percent is made up by high priority sites with slope gradients between 40 and 55 percent and soils deeper than 2 feet. These sites can be cleared efficiently. They should produce a good soil cover and probably some increased yield of water.

Slopes having gradients of 55-70 percent and soils more than 2 feet deep are questionable for clearing until research determines whether increased water yield will pay the conversion costs on long steep slopes, and whether extensive clearing will produce problems of soil stability. These sites include about 15 percent of the experimental forest.

In fitting brush conversion to the experimental forest, areas to be cleared for increased water yield will be selected first. Then selection of additional conversion areas will be based on fire control needs and on accessibility of the areas to men and equipment (Bentley and White, 1961). As far as possible the wide fuel-breaks, on which the brush fuel will be changed to a grass cover, will include the areas of high priority for other purposes. To connect the fuel-breaks into a complete system, preference will be given to clearing brush from sites that will yield water even though the increased yield may be small.

Obviously, brush conversion should be done on the most accessible and least steep areas, on which the work is most feasible. Thus, many fuel-breaks will be located in canyon bottoms and on rounded ridgetops to include a minimum of steep slopes. Areas cleared of brush on steep slopes will be kept individually small so that possibilities of increased erosion from brush removal will be at a minimum.

Despite the generally unfavorable site conditions in the San Gabriel Mountains, brush conversion on areas selected for a specific purpose can develop a new vegetation pattern that will greatly benefit control of fire and will result in more intensive multiple-use management.

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A soil survey of the San Dimas Experimental Forest showed that steep slopes or shallow soils, or both, occupy 90 percent of the area and greatly limit the opportunities for conversion of native brush to a different plant cover. Criteria are given by which sites can be selected for brush conversion to intensify land management.

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No. 62 November 1961

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HELICOPTER SOWING OF BURNED WATERSHEDS ON THE SAN DIMAS EXPERIMENTAL FOREST, 1960

By

Jay R. Bentley, Verdie E. White, and Lisle R. Green

Helicopters have proved well adapted for sowing seed to establish a temporary herbaceous cover on burned chaparral watersheds in southern California. Fixed-wing aircraft can sow large acreages rapidly and cheaply, but the helicopter has the advantage that it can do close, careful work in steep terrain with a high degree of pilot safety. Sowing by helicopter was the only feasible method of spreading seed on the San Dimas Experimental Forest after it was burned by wildfire in July 1960. Ground equipment could not be used on the steep terrain, and fixed-wing aircraft would not allow the control of seed distribution needed for experimental purposes. Many small areas were sown with a variety of species in various combinations. Other areas were left unsown as experimental checks. The procedures developed during this complex sowing operation can help guide other kinds of aerial broadcast sowing jobs.

PROCEDURES AND COSTS

A total of 13,496 acres were sown in 132 individual areas: 70 small watersheds and linear plots of 3 to 26 acres each; 18 intermediate areas of 26 to 103 acres each; and 44 larger areas, averaging 254 acres each.

Grasses were sown at 10 pounds per acre on most of the acreages, and mustard at 5 pounds per acre on a few areas. The helicopter flying was contracted for approximately $70.00 per hour of actual flight time.

The average cost per acre for each phase of the sowing operation was:

Marking areas	0.04
Hauling seed	0.05
Loading seed	0.14
Keeping records	0.07
Helicopter flying	0.83
Total	$1.13

The cost of each phase naturally was higher for the small areas than for the larger operational units. Average costs per acre for areas of different sizes were approximately $2.00 for small areas, $1.50 for intermediate areas, and $1.00 for the larger areas.

These costs include all equipment operation and all salaries except those of technical project men who planned and directed the work. Costs for purchase of seed and for seed storage and mixing are not included.

NUMBERING AND MARKING AREAS

Each sowing area was outlined on a large-scale planning map and numbered as soon as its specific treatment had been decided. The areas were numbered consecutively as the planning progressed. A duplicate of the map was used in the field to direct the sowing operation. All areas to be left unsown as experimental controls were colored yellow on the map as a constant caution not to fly over them.

The acreage, species to be sown, rates of sowing, and total seed requirements were tabulated for each area. Copies were used by the project planner, the seed mixing crew, and the man who directed all of the helicopter flying. This detailed procedure made it possible to sow the many areas as planned with only a few minor mistakes.

Boundaries of areas to be left unsown were marked by dropping small paper bags of lime which burst on contact with the ground and left readily visible markers. The boundaries of areas to be sown were similarly marked during reconnaissance flights just ahead of sowing. Some markers were eliminated by rain and had to be replaced.

The small experimental areas were surveyed and staked ahead of sowing, and the boundaries marked with flags. One or more flagmen guided the helicopter pilots during sowing to make sure the correct areas were sown. The intermediate and large areas were sown without flagmen.

HANDLING AND MIXING SEED

All of the seed was delivered to the experimental forest and stored until inspected for compliance with county seed laws. The seed was mixed at this location instead of at a mill because of the numerous mixtures to be used and the necessity for planning treatments after the seed had been delivered.

The work in handling and storing the seed in bulk was done by a Conservation Camp crew furnished by the California State Division of Forestry. They weighed, mixed, and bagged the simple mixtures of 2 species which were used in large quantity. Crews of 4 men under the direction of a technician mixed the more complex mixtures. A crew of this size could put together a mixture of 4 species at the rate of about 4,000 pounds a day. Mixtures containing more species were time-consuming and would not be practical for mixing in large quantities. However,

Loading and refueling the helicopter.

Helicopter landing at a temporary heliport.

Catching seed in sack, with seed distributor removed, during calibration of the seeder.

hand mixing proved feasible for simple mixtures if only 100 to 200 pounds of seed were mixed at a time.

The seed was bagged in 50-pound lots for ease in hauling and in loading the helicopter. Each bag of seed covered 5 acres. Rice hulls were mixed with the seed sown on the small and intermediate experimental areas, to bring each bag of seed up to a uniform volume. This made it possible to sow the various seed mixtures without constant recalibration of the seeders. For the seed sown on the large areas, however, rice hulls were not added because a test showed that the most complex mixtures were evenly distributed without the hulls (Edmunson, et al., 1961).

The best volume of seed and rice hulls per bag was determined by trial. A 20-gallon volume proved too small because this volume of seed for 8 of the species weighed less than 50 pounds (table 1). A 25-gallon volume per bag was adequate for all of the mixtures that were used, even though seed of 3 species weighed less than 50 pounds in 25-gallon lots. Blando brome was the only species with seed weighing appreciably less than 50 pounds per 25 gallons. Seed of this species presented other difficulties in sowing because it did not flow freely through the seeders. Where it was sown alone in plot trials, the desired rate was obtained by flying twice over the plot.

The amount of rice hulls to add to seed of an individual species or mixture to bring it to a given volume can be estimated from the data in table 1. For example, in a 50-50 mixture of Hardinggrass and tall wheatgrass at 25 gallons per 50 pounds of seed, add 10 pounds (.50 x 20) of hulls for the Hardinggrass and 1 pound (.50 x 2) for the wheatgrass, making a total of 11 pounds of hulls, which is the same amount determined by trial. In a 70-30 mixture of ryegrass and mustard, add 7.7 pounds (.70 x 11) of hulls for the ryegrass and 6.3 pounds (.30 x 21) for the mustard, making a total of 14.0 pounds. For some mixtures, however, the calculated amount of rice hulls to be added may not be so exact because seeds of various sizes and shapes may combine differently with the rice hulls, and rice hulls do not have a constant weight per unit of volume.

A crew of 5 men for hauling seed and loading the helicopter kept the operation moving smoothly. Most of the loading was done by two men. When sowing was interrupted by inclement weather the crew built heliports or helped mix seed.

OPERATING THE HELICOPTERS

The helicopters were flown from ten heliports located adjacent to roads and well situated for safe and efficient landing and take-off. Each heliport was of sufficient size for servicing and operating two helicopters and for storage of two truckloads of seed. Each landing pad was on a cleared area of at least 60 feet diameter. A strip of bright-colored tape on an iron rod close by the pads served as a wind indicator.

Table 1.--Approximate weights of seed and rice hulls in bags of 20 and 25 gallon volume, for different species and mixtures

Species or mixture	Volume of bag			
	20 gallons		25 gallons	
	Seed	Hulls	Seed	Hulls
	- - - - - - - - Pounds	- - - - - - - - - -		
Ryegrass	50	6	50	11
Blando brome	31	0	38	0
Ryegrass 4[1], Blando 1	50	0	50	6
Black mustard	50	15	50	21
Ryegrass 7, mustard 3	50	7	50	14
Tall wheatgrass	42	0	50	2
Pubescent wheatgrass	37	0	46	0
Intermediate wheatgrass	43	0	50	1
Hardinggrass	50	14	50	20
Harding 1, tall wheatgrass 1	50	6	50	11
Smilo	50	19	50	27
Veldtgrass	40	0	50	5
Veldt 1, tall wheatgrass 1	41	0	50	3
Tall fescue	50	3	50	8
Orchardgrass	44	0	50	2
Big bluegrass	39	0	48	0
Rose clover	50	18	50	24
Rose 1, tall wheatgrass 1	50	8	50	13
Subterranean clover	50	16	50	22
Woolypod vetch	50	15	50	21

---

[1] Numerals indicate parts by weight.

Most of the sown acreage was within a mile of a heliport--an important factor in keeping down the cost of sowing by helicopters, which carry relatively small loads. For the 200-pound seed loads commonly carried in this operation, flight time to and from the sowing areas within 1 mile cost about 3 to 15 cents per acre. The cost was 35 to 40 cents for areas 3 miles away, and would have been more than 60 cents if areas were located 5 miles from the heliport. On non-research jobs, flight-time costs might be reduced by decreasing the sowing rate per acre or by covering more acres per load.

Sowing of small experimental areas required extra reconnaissance flights and ferry flights between heliports. Also extra flight time was required for sowing, mainly because of short swaths and light loads. The average costs per acre of different kinds of flights for areas of different sizes were:

Size of Area	Kind of Flight			
	Sowing	Reconnaissance	Ferry	Total
Small	$ 1.20	$ 0.13	$ 0.09	$ 1.42
Intermediate	0.99	0.08	0.16	1.23
Large	0.67	0.05	0.02	0.74

Two helicopters could be operated simultaneously from a heliport if a different sowing area were assigned to each pilot and separate flagmen stationed at each area.

The seeder attached to each side of a helicopter included a 50-gallon hopper, a wire agitator in the bottom of the hopper, a shut-off gate, and a blower. The agitator, gate, and blower were operated by three separate motors. The rate of seed movement from the hopper was regulated by a notched slide which was manually adjusted for each seed mixture. Spread of seed from the blower was guided by a flat, fan-shaped distributor.

The seeders were calibrated many times because of changes in seed mixtures, or moves from large areas to small plots. To calibrate a seeder, a full bag of seed was placed in the hopper and the distributor removed from the blower. The slide was set at an estimated point. With the agitator and blower operating, the rotor was revved up to flight RPM and the seed was caught in a sack behind the blower while the gate was opened for a given period of time. The slide was readjusted and the process repeated until the correct amount of seed was caught from each seeder. The correct amount of seed to catch from each seeder during a 30-second run was 10 pounds for a rate of 10 pounds per acre sown in 40-foot swaths at a 45 mile per hour flying speed, as used in the sowing operations. For a 50-pound bag of seed containing an additional 5 pounds of rice hulls, the correct amount to catch was 11 pounds of seed and hulls combined.

Weather greatly influenced the speed and efficiency of the sowing operation. During the 37-day period from October 23 to November 29, excessive wind prevented sowing on 4 days and cloudy or rainy weather, often with wind, on 6 additional days. On calm mornings the sowing was started at daybreak and stopped when wind speed reached about 10 miles per hour. Flying usually continued for 2½ to 3½ hours and averaged slightly more than 3 hours per day. The allowable maximum of 6 hours was reached on only one day. Fog which prevented flying of fixed wing aircraft from valley airports did not greatly hamper operations of the helicopters, which were based above 2,000 feet elevation.

A timekeeper recorded the flights of each helicopter from take-off to landing. The log included minutes in the air, amount and kind of seed carried, and the number of the area sown. This intensive record keeping, required under the helicopter contract, made possible a continuous check for mistakes in sowing and a detailed analysis of the helicopter operation at the end of the job.

SUMMARY

From October 23 to November 29, 1960, seed of herbaceous plants was sown by helicopter on 13,496 acres of burned-over chaparral watershed on the San Dimas Experimental Forest. This acreage included 70 small experimental areas of 2 to 26 acres, 18 intermediate areas of 26 to 103 acres, and 44 larger areas. Seed of 15 species was sown in various combinations. Rice hulls were added to the seed for each small and intermediate area to bring each 50-pound bag up to a uniform volume. Cost of the sowing operation, exclusive of seed and seed mixing, was $2.00 per acre for the small areas, $1.50 for the intermediate, and $1.00 for the larger areas. The procedures developed for this complex operation are described as a guide to other helicopter sowing jobs.

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MISCELLANEOUS PAPER NO. 63
NOVEMBER 1961

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THE FUEL-BREAK SYSTEM FOR THE SAN DIMAS EXPERIMENTAL FOREST

Jay R. Bentley & Verdie E. White

PACIFIC SOUTHWEST
FOREST AND RANGE
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BERKELEY, CALIFORNIA

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ACKNOWLEDGMENTS

The San Dimas Experimental Forest is maintained by the Forest Service, U. S. Department of Agriculture in cooperation with the California Division of Forestry. Since 1947 this has been a joint research project with the California Division of Forestry, which participates in program planning and provides financial support. Other long-term cooperators are the Los Angeles County Flood Control District, the Los Angeles County Fire Department, and the University of California, which provide staff or other support or use research facilities at the experimental forest.

Special recognition is due these agencies and the California Department of Water Resources for assistance with emergency rehabilitation work after a wildfire in July 1960. Their cooperation made it possible to restore experimental facilities and start emergency research on methods of managing chaparral watersheds for more effective control of fires, floods and erosion, and water yield.

Research policy and program formulation at the San Dimas Experimental Forest are guided by the following Advisory Committee:

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THE FUEL-BREAK SYSTEM
FOR THE SAN DIMAS EXPERIMENTAL FOREST

By

Jay R. Bentley and Verdie E. White

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Miscellaneous Paper No. 63 November 1961

U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
BERKELEY, CALIFORNIA

THE FUEL-BREAK SYSTEM
FOR THE SAN DIMAS EXPERIMENTAL FOREST

By
Jay R. Bentley and Verdie E. White

Relatively few fires escape initial suppression effort in continuous brush on the steep mountain terrain of southern California, but those that escape often defy later fire-control action. The most intensive, coordinated ground and air attack may not control large fires until damage and fire-fighting costs are beyond tolerable limits. One approach to a solution of this problem lies in the modification of the fuel on key fire-control areas within expanses of heavy brush fuels. Much work has been started to break up the brushfields of southern California. With particular emphasis on areas critical to fire-control effort, the FUEL-BREAK program[1] was organized in 1957 to apply this principle and work out improved methods. However, the first opportunity to plan and start work on a complete fuel-break system did not occur until the San Dimas Experimental Forest was burned over by wildfire in 1960. This report describes the system planned for the experimental forest.

Fuel-Break Objectives

Fuel-break systems aim at breaking extensive brushfields into small manageable units by converting brush to a new cover of low fuel volume on wide strips or blocks at strategic locations. These strips or blocks are called fuel-breaks, which will provide safer access for men and more effective use of highly developed fire-control techniques. Proper locations and adequate widths for the breaks are decided by experienced fire fighters.

The native brush on fuel-breaks is converted to a new plant cover that will protect the soil. This brush conversion process requires removal of all woody vegetation except occasional shrubs and trees left for esthetic or other reasons. The natural brush regrowth must be eliminated, which requires chemical spraying of sprouts and seedlings for a few years, and a new cover must be established as soon as possible. It should be made up of herbaceous plants, mainly grasses, unless other adapted species of lower flammability are found and techniques developed for establishing them. The objective is to have a new cover that is relatively stable and easily maintained over the years.

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[1] The FUEL-BREAK program is conducted cooperatively by the California State Division of Forestry, the Los Angeles County Fire Department, and the U.S. Forest Service.

Besides aiding in fire control, fuel-breaks can help intensify management of brushland watersheds. They can be designed to include considerable acreage of sites from which increased water yield may be expected after brush removal; they can add to the amount of brushland "edge effect" and thus improve wildlife habitat; they can grow forage for use by deer and in some places by livestock; and they can open up and protect recreation values.[2]

Planning a complete fuel-break system for the future is advisable on each management unit even though the entire plan cannot be put into effect at once. An advance plan will assure best use of funds and manpower as they become available. It will make possible quick action if part or all of a unit is burned over by wildfire. Then quick action is essential. The brush can be eliminated on fuel-breaks after a hot burn at a fraction of the cost required to remove an unburned brush cover--provided that the work is started soon after the fire. And a complete plan will show the size of budget required to put brushland watersheds under more intensive management with better fire protection in the future.

The Próblem Area

The San Gabriel Mountains, where the experimental forest is located, represent extremes in steep terrain and shallow soils. Wide-scale conversion of the native brush to a new vegetation cover is not advisable; it is hardly possible. On selected areas, however, conversion for specific purposes is both possible and advisable.

In a soil survey of the experimental forest, only about 10 percent of the acreage was mapped as having slopes under 55 percent in gradient and soils more than 2 feet deep. An additional 4 percent had slopes under 55 percent gradient with shallower, less productive soils.[3].

Bulldozers and other heavy ground equipment can be used on much of this 14 percent of the land to remove brush, to sow grass, and to spray chemicals on brush regrowth. Bulldozers also can be used on some of the narrow ridgetops and canyon bottoms not delineated by the survey. Including these areas, the total acreage workable with a bulldozer, and accessible without expensive trail construction, probably amounts to less than 15 percent of the experimental forest. This is the area on which brush conversion can be done efficiently and positively.

On the remaining acreage the brush conversion job would have to be done with hand labor and by aerial applications of seed and chemical. Aerial sowing may be fairly cheap but it produces erratic results. Aerial spraying is economical and ordinarily is effective. However, the final cleanup of brush sprouts must be done by hand labor, which is a costly operation on inaccessible steep terrain.

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[2] Bentley, Jay R. Fitting brush conversion to San Gabriel watersheds. U.S. Forest Serv. Pacific Southwest Forest and Range Expt. Sta. Misc. Paper 61. 8 pp., illus.

[3] Bentley, J. R. Op. cit.

Thus accessibility to men and equipment is a major factor determining which areas are selected for brush conversion. Most of the acreage is accessible only by long and arduous foot travel, which makes the job expensive. Fortunately, the areas most readily worked by equipment or on foot are also the areas most accessible for fire fighting, and they are at strategic locations where wide breaks in the brushfields are most needed.

Fire-Control Access

A fire-control access map (fig. 1) was prepared from data which had been obtained in a pre-attack survey of the area. These data included locations of all fire-control roads, the existing or potential tractorways and hand line locations, and other essential information.[4] The access map served as a guide in locating fuel-breaks on the most accessible and strategic ridges and roads. Also, it showed the areas most readily worked by equipment and those where manual work would be required.

In general, access over the experimental forest is good. A complete network of roads encircles it, and a road extends along the ridge separating its two main drainages. The upper part of the experimental forest is accessible by county highway and the lower part by several other roads. The major canyon bottoms have roads into them.

Access by all-wheel-drive vehicles is planned along some main ridges and in the drainage bottom at a critical location below headquarters. Tractor ramps give access to the strategic ridgetops.

This fire control access map, along with maps showing the most favorable sites for brush removal to improve water yield and other resources,[5] was used in planning the brush conversion job.

Primary Fuel-Breaks

A system of primary fuel-breaks (fig. 2) was first laid out to represent the minimum system considered essential for aiding in control of large fires. These breaks are along the prominent ridges bordering two major drainages and on lateral ridges across the "front country" near the southern boundary of the experimental forest. Primary breaks also were laid out to break one major drainage into three large areas. The objective of the primary breaks is to exclude a large fire from, or confine it to, relatively large units of a few thousand acres each.

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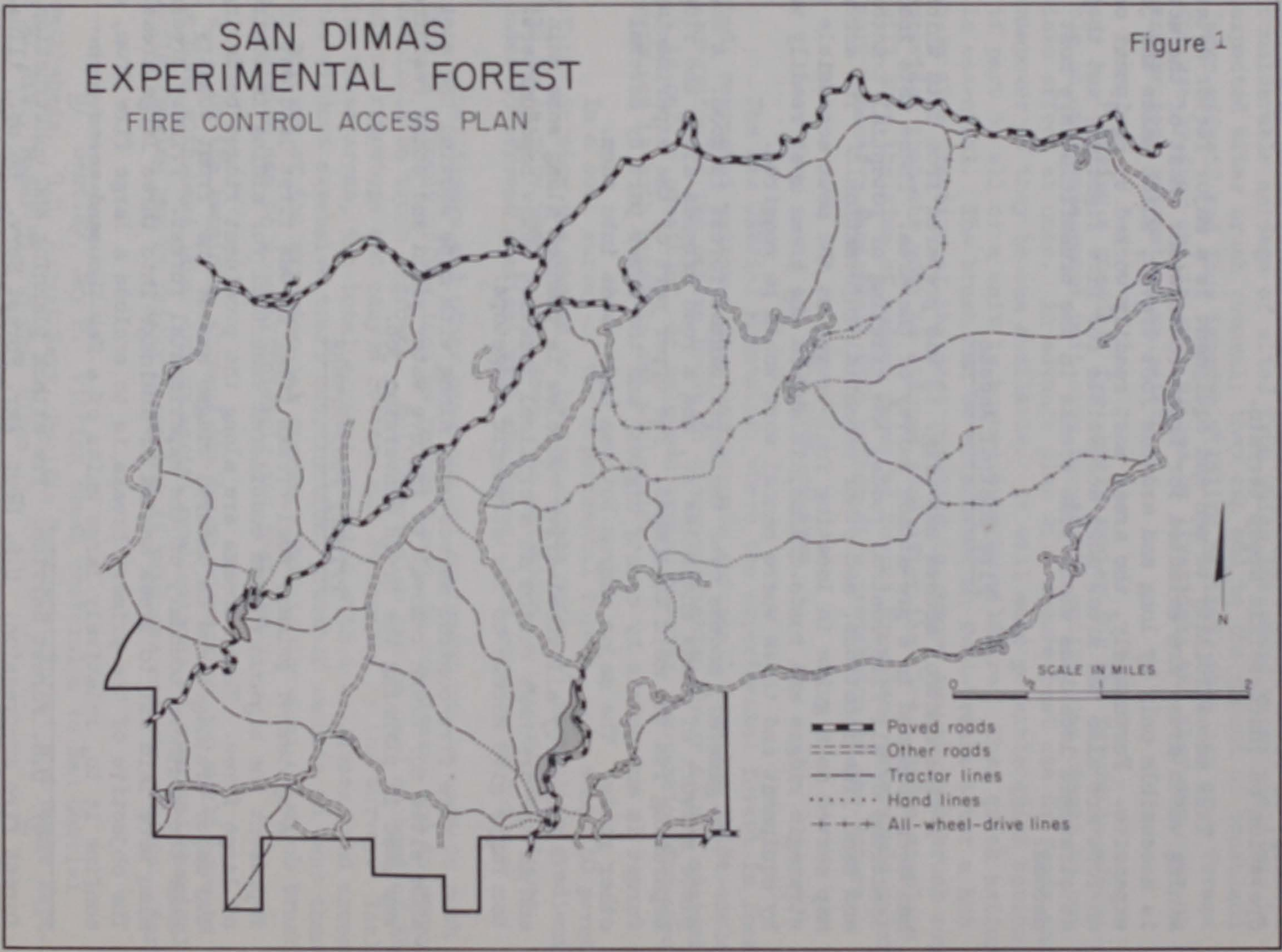
[4] U.S. Forest Service. Pre-attack planning and construction for forest fire suppression. U.S. Dept. Agr. Forest Serv. 66 pp., illus. 1959.

[5] Bentley, Jay R. Op. cit., figs. 1 and 2.

Figure 1


SAN DIMAS
EXPERIMENTAL FOREST
FIRE CONTROL ACCESS PLAN
SCALE IN MILES
0
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2
N
Paved roads
Other roads
Tractor lines
Hand lines
All-wheel-drive lines

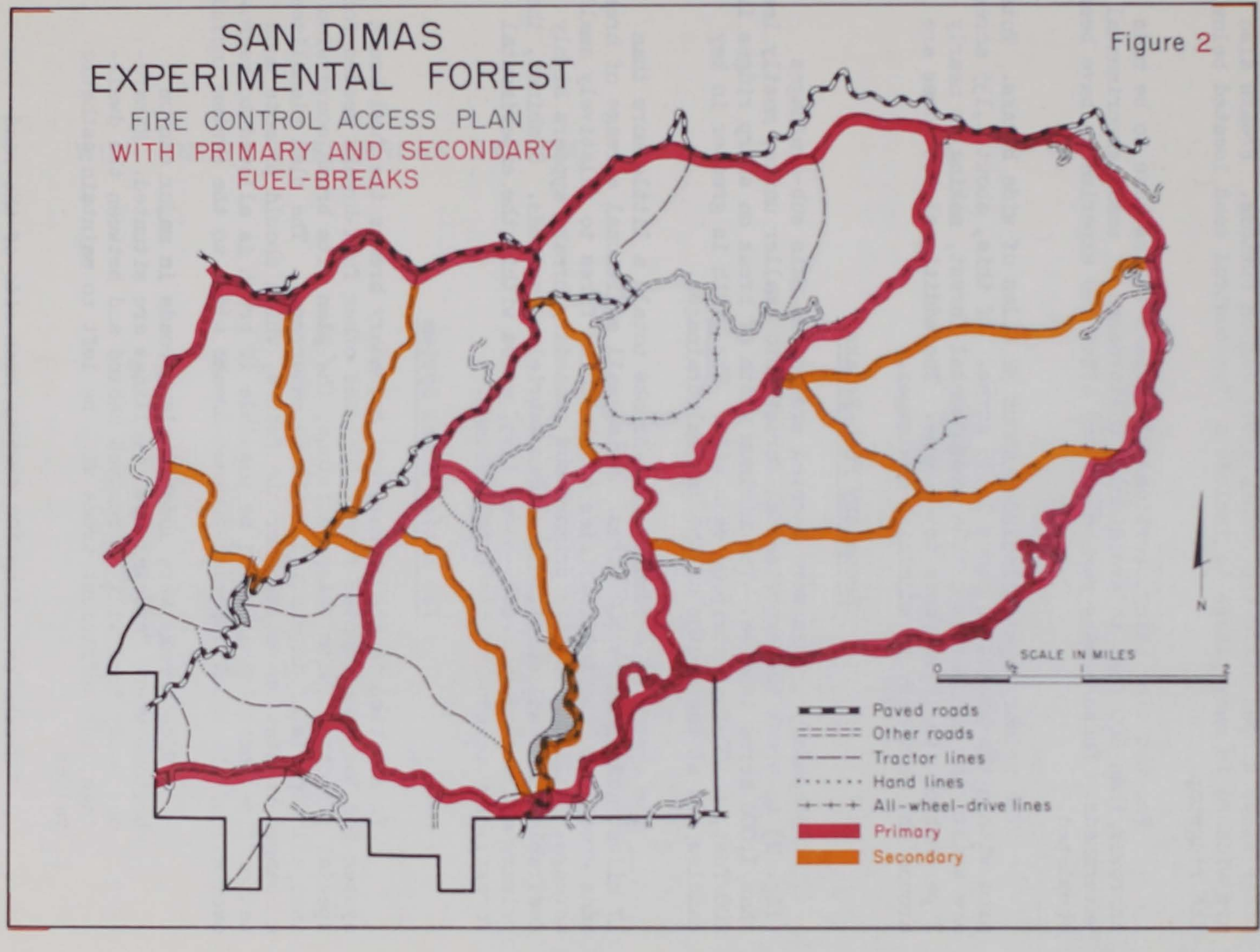


Figure 2

SAN DIMAS EXPERIMENTAL FOREST

FIRE CONTROL ACCESS PLAN WITH PRIMARY AND SECONDARY FUEL-BREAKS

N
SCALE IN MILES
0
½
1
2
Paved roads
Other roads
Tractor lines
Hand lines
All-wheel-drive lines
Primary
Secondary

The primary breaks have a minimum width of about 400 feet. Portions are wider at the most critical saddles and down ridge points or other steep slopes where the breaks cross canyon bottoms. Breaks also are widened in many places to include a fire-control road located below the ridgetop.

For the time being, portions of certain breaks have to be made narrower than 400 feet to avoid undue disturbance of small experimental watersheds. These breaks can be widened after the experiments have been completed.

The primary system includes about 32 miles of wide breaks. Total area within the breaks is about 1,535 acres. Of this, about 1,135 acres are within the boundaries of the experimental forest, making up nearly 7 percent of its 17,000-acre total area. The additional 400 acres are around the periphery in adjoining drainages.

Secondary Fuel-Breaks

Secondary breaks were located around the main sub-drainages (fig. 2) to break the experimental forest into smaller units, mostly less than 1,000 acres in area. The minimum width of break on sharp ridges is 200 feet, a 100-foot strip on each side. The width is greater in key saddles and at the mouths of the lateral drainages.

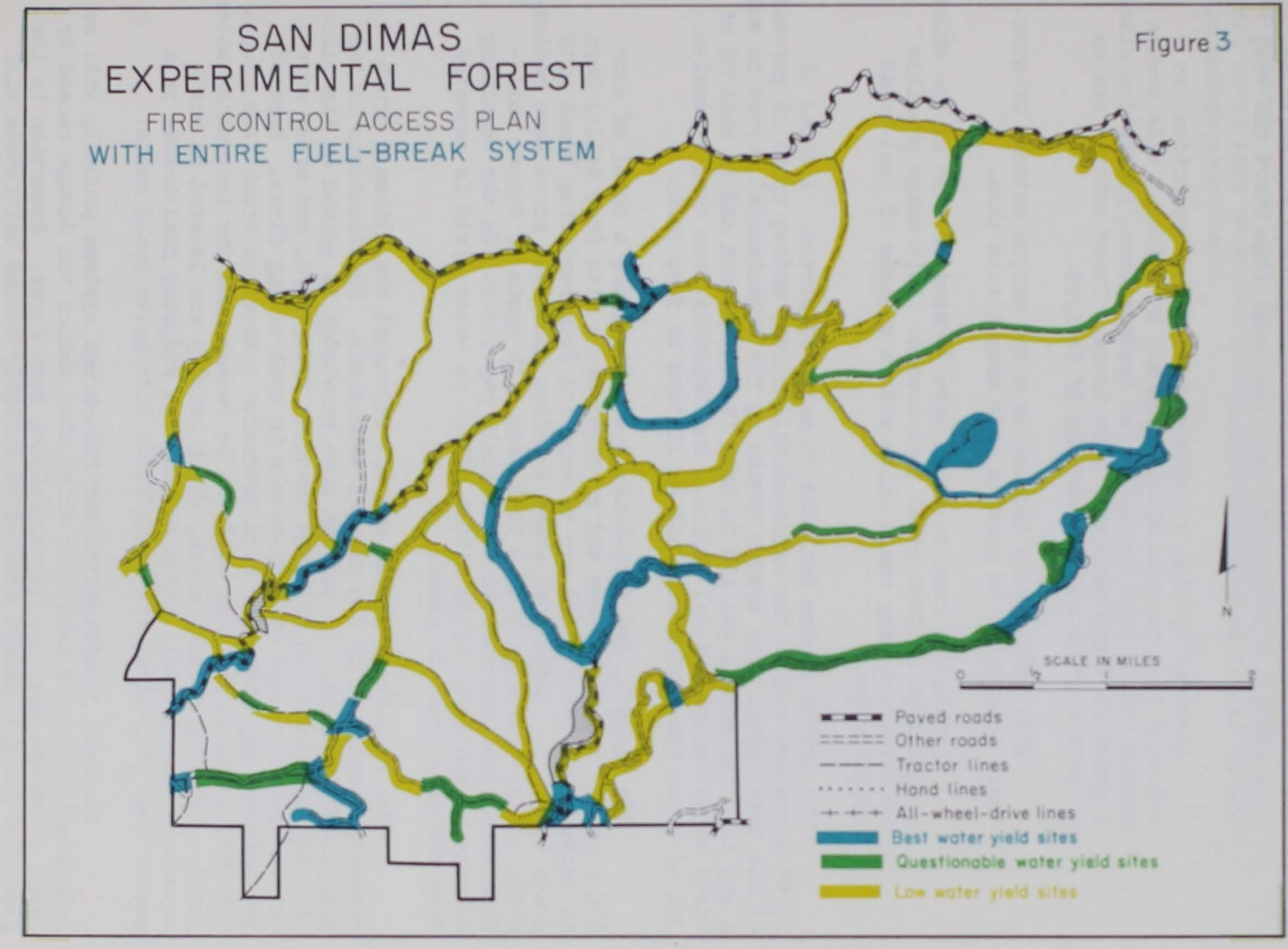
The system of secondary fuel-breaks totals a little more than 17 miles, and includes 402 acres. This small additional acreage of breaks adds greatly to the possibilities of confining fires to relatively small acreage. Building of both primary and secondary breaks appears highly desirable under all conditions on San Gabriel watersheds. Combined, the primary and secondary breaks cover 1,537 acres within the experimental forest, or 9 percent of its total acreage.

The Entire Model System

In addition to the primary and secondary breaks the fuel-break system for the experimental forest includes other fuel-breaks needed for special purposes. With these additions, the plan fits brush conversion into all aspects of intensive brushland management. The plan visualizes a changed vegetation pattern for the future, which should promote much better fire control than would be possible if brush is allowed to regrow over all of the area. Special-purpose breaks added to the system include:

> Wide breaks were located along roads in major canyon bottoms where "special-use" dwellings are situated. Hazardous woody fuel will be removed behind and between the dwellings, but sufficient trees will be left to maintain esthetic values.
>
> Breaks extending 100 feet on each side of the road were located along all fire-control roads not included within primary and secondary breaks. Specimen trees or shrubs will

Figure 3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FIRE CONTROL ACCESS PLAN
WITH ENTIRE FUEL-BREAK SYSTEM
N
SCALE IN MILES
0
½
1
2
Paved roads
Other roads
Tractor lines
Hand lines
All-wheel-drive lines
Best water yield sites
Questionable water yield sites
Low water yield sites

be left, where possible, to make the landscape more pleasing. These breaks will allow safer use of the roads and serve as fire-control lines under some fire conditions where the road itself is not an adequate break.

Areas of special value were marked for protection by removing fuel-hazards within them and by building wide breaks around them. Such areas are the headquarters, plantation sites, a grove of large ponderosa pine trees. Other natural groves of native trees may be included if desired.

Wide breaks were located in a few canyon bottoms of strategic importance to provide safe access into them.

Breaks 200 feet in width were located on some of the short ridges that connect other fuel-breaks. This makes possible breaking out many small units with a minimum of fuel-break construction.

The entire system includes 74 miles of breaks. A total of 2,405 acres are within the experimental forest, adding up to 14 percent of its total area. The system breaks up the experimental forest in such a way that the breaks can aid in both initial attack and in control of fires which escape initial action. But benefits from this extensive job of brush conversion will not be limited to fire control.

For example, the fuel-break system includes a total of some 600 acres in canyon bottoms and on other sites with deep soils; here an increase in water yield can be expected from replacing brush with grass (fig. 3). Additional areas totaling about 400 acres have medium-depth soils--typically 2 to 3 feet deep with spots of deeper soil--from which some increase in water yield may occur. On the remaining acreage of shallower soils little effect on water yield is expected from changing brush to grass.

The fuel-break system may not represent the ultimate brush conversion endeavor on San Gabriel watersheds. Modifications in the plan undoubtedly will be made as more knowledge is gained on the place of brush conversion in wildland resource management, and after more experience in the use of fuel-breaks in controlling fires. Research now underway may show that more extensive removal of brush from slopes with medium depth and deep soil can be recommended for increasing water yield. Clearing of such areas, which usually are located on north exposures, can connect canyon bottoms and ridgetop fuel-breaks in a manner that will break the brushfields into quite small units.

Economic justification for fuel-break systems probably will be judged mainly by the extent to which they reduce the damage caused by large fires and the cost of controlling such fires. Reduction in the flood and erosion hazard created on recently burned watersheds will continue to be the primary management problem in the San Gabriel Mountains.

Because these watersheds are perched directly above highly developed urban and industrial areas, the potential flood damage after fire is estimated at hundreds of dollars for each acre that is burned over. As urban development moves into watershed areas, life and property add new dimensions to the damage potential.

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EUCALYPTS IN HAWAII:
a survey of practices and research programs

Russell K. LeBarron

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EUCALYPTS IN HAWAII: A SURVEY OF PRACTICES AND RESEARCH PROGRAMS

By Russell K. LeBarron

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Miscellaneous Paper No. 64 1962
U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
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EUCALYPTS IN HAWAII: A SURVEY OF PRACTICES AND RESEARCH PROGRAMS[1]

By
Russell K. LeBarron
Research Forester

The systematic forest planting of eucalypts and other exotic trees in Hawaii began almost 100 years ago. According to Margolin (1911) the first commercial stand was established in 1882. It produced fuel for a sugar cane plantation in a district where supplies of native trees had been depleted. More recent research (Bryan, 1960) indicates that the first large planting occurred before 1870. Later eucalypts came to be recognized as the best all-around trees in many situations. They were grown extensively to protect denuded watersheds, as shields against the almost daily trade winds, and for the production of fuel and fence posts. On the whole, forestation for watershed protection remained the dominant aim until rather recently. Today, emphasis is directed to the use of eucalypts for lumber and veneer.

By 1910 cultural practices for the nursery propagation of eucalypts were well systematized, and 54 species had been planted. In many respects practices described by Margolin in 1911 differed little in detail from those reported by Cossitt in 1960. In principle, standards for selection of planting sites and methods for site preparation and field planting were much the same as those recommended by Zschokke in 1930. Most of these standards and methods are still in use. The major recent changes have been the substitution of heavy tractors for hand tools and animal-drawn plows in clearing sites before planting.

The total of all tree plantings in the Islands by 1960 was estimated by State Forester Walter W. Holt at about 90,000 acres, impressive for a state with a land area of only four million acres. The fraction of this planting which consisted of eucalypts is not known, but it must be more than half. Of the total trees originally planted, many were used as windbreaks and for small woodlots. The net acreage of surviving tree plantings is substantially less than the total of 90,000 acres. Some acres have been destroyed by a variety of agents, such as domestic and feral livestock, competing vegetation, and fires. Some have been harvested for fuel and other products. Probably more have been removed to clear the land for cultivation and pasture. The present net acreage of plantings, not counting windbreaks, has been estimated by U. S. Forest Service Research Center Leader R. E. Nelson at about 50,000 acres. Of this acreage, 70 percent is composed of eucalypts, broken down as follows:

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[1] Based on a report to the Second World Eucalyptus Conference, São Paulo, Brazil, August 13-26, 1961, sponsored by the Food and Agriculture Organization of the United Nations.

Species	Acres
E. robusta	23,000
E. globulus	4,000
Other eucalypts	8,000
Total	35,000

CLIMATE AND SOILS

The Hawaiian archipelago is of comparatively recent volcanic origin. The largest and newest of the principal islands, Hawaii has active volcanoes and thus is still in the stage of building. The maximum elevation is 13,796 feet, but most of the land lies below 5,000 feet and half is below 2,000 feet.

TEMPERATURES

Temperatures in the areas suited to production of timber can be described as warm with remarkably little daily or seasonal variation. According to the Hawaii Water Authority (1959), temperatures rarely exceed 90°F., except at the driest locations, and minimums at elevations below 2,000 feet seldom drop below 55°F. The mean daily temperature at low elevations ranges from 10°F. to 18°F. The difference in mean temperature between the warmest and coldest months is only 5°F. to 8°F. In the elevational zone from 2,000 to 6,000 feet, the atmosphere is distinctly cooler, but freezing temperatures are rare. The Honaunau Forest of the Bishop Estate on the western side of the Island of Hawaii reasonably represents the kind of land that is being planted. The lowest elevation is 2,200 feet and the highest is somewhat over 4,700 feet. Carlson and Bryan report (1959) that "temperatures range from 80°F. down to 32°F." and "there may be occasional light frosts at 4,750 feet." A temperature of 26°F. has been reported at 5,100 feet elevation in the Hilo Forest Reserve (Bryan, 1947). District Forester Karl H. Korte, Maui, states that above 5,000 feet heavy frosts occur at night during the winter months.

PRECIPITATION

Rain falls abundantly throughout the islands as a whole. The median annual rainfall is 72 inches, but wide local variations exist (Hawaii Water Authority, 1959). On six of the seven largest islands the range extends from less than 18 to more than 250 inches per year. In some areas which become shrouded in cool, heavy clouds almost daily, fog drip from forest vegetation may add significantly to the total precipitation.

On Maui and Hawaii, which have the highest mountains, the greatest precipitation occurs on the easterly windward sides of the islands at relatively low elevations from 2,000 to 3,000 feet.

The rainfall in areas available and suitable for growing timber is well distributed throughout the year. Three typical examples are given to illustrate rain forest, moderately wet, and relatively dry conditions (table 1).

WIND

Wind plays a prominent part in creating the environment of the Islands. The steady, almost daily trade winds from the northeast and east blow at the rate of 10 to 18 miles per hour (Hawaii Water Authority, 1959). They bring rain and cause rain shadows on the leeward sides of the principal mountains. Trees in windward forest edges and other exposed vegetation almost all show bending and distortion from this constant force. Trade winds are the reason for extraordinarily extensive planting of tree belts to shelter cultivated fields, homes, and domestic livestock.

Violent windstorms have caused considerable damage to trees in the form of broken limbs, snapped stems, and uprooting. Such damage may become a factor of major silvicultural importance when thinning and harvesting forest crops become common. Between 1951 and 1961 four true hurricanes and a number of other tropical storms with winds up to 100 knots have pummeled the Islands, according to R. E. Nelson. Both E. robusta and E. saligna were damaged severely in some instances.

Table 1.--Rainfall in three locations in Hawaii, by months[1]

Month	Piihonua, Hawaii	Hana, Maui	Waimea, Hawaii
	Inches	Inches	Inches
January	12.18	7.81	4.86
February	16.01	6.31	4.47
March	14.88	7.64	4.95
April	17.52	9.31	4.25
May	15.18	5.24	3.12
June	13.47	3.67	2.25
July	17.62	4.53	2.99
August	20.23	5.38	3.24
September	13.81	5.33	2.24
October	13.17	4.86	2.59
November	18.63	6.34	3.67
December	19.04	8.89	5.13
Total	191.74	75.31	43.76
Basis (years)	11	32	40

[1] U.S. Department of Agriculture. Climate and Man. Yearbook of Agriculture. 1,248 pp., illus. Washington, D. C. 1941.

SOILS

Virtually all soils in Hawaii have developed from lava and volcanic cinder. Those available for timber production (not occupied for agriculture, cities, and other special purposes) are generally shallow and many are almost unbelievably rocky for highly productive timber sites. Lava solidifies into two greatly differing forms of rock--pahoehoe and aa. Pahoehoe hardens in ropy continuous masses to form relatively impervious sheets. Subsurface drainage often is poor. Aa hardens while in motion to form broken masses of porous clinkers that are highly pervious to water. Under the influence of moderate to heavy rainfall, warm temperatures, and abundant vegetation, lava rapidly weathers into fine-textured soil. Depth and drainage differ greatly within short distances in the rough, broken topography.

In areas suitable for growing timber, soils are usually acid in reaction--sometimes strongly acid. Organic litter decomposes and disappears very quickly. In most places in eucalypt forests mineral soil is covered only by litter that has fallen within less than a year.

Except in the areas of heaviest rainfall, ponds and streams that run continually are uncommon. Most water from rains penetrates into crevices in the underlying lava rock and sinks to great depths.

SPECIES

The total number of species of eucalputs that has been introduced is not known, but undoubtedly exceeds 100. Presumably many kinds have been brought in at different times without any formal records. However, chronicles of introductions by the Hawaii Forestry Division have been rather well maintained, and this organization has been instrumental in propagating and testing many species. The records and publications of the Division therefore provide the basis for most of the descriptions in this section.

CHECKLIST OF COMMON NAMES

A list of common names of many trees that have been planted in Hawaii has been prepared by the Hawaii Forestry Division and the Forest Service (Bryan and Walker, 1962). It contains 77 eucalypts (table 2). Latin names are those used by Blakely (1955).

This checklist will help standardize terminology and thus avoid uncertainty and confusion in records and reports.

Many common names have been modified from those of Australia to conform with current usage in Hawaii and with naming practices of the Forest Service. Some of these common names will appear cumbersome and strange to those who are familiar with Australian terminology, but they were necessary for several valid reasons. The Federal Trade Commission restricts the use of "mahogany," when describing wood products, to the genus Swietenia. "Gum" is ambiguous because it is a local name for several trees in the United States. "Ash" means Fraxinus to English-speaking people in North America and "mountain-ash" is Sorbus. We can use such names as swampmahogany (E. robusta) only by using that form or by adding the Latin generic name. The problem of common names for the more widespread and abundant species--E. globulus, E. robusta, and E. saligna--has been neatly solved by calling them "bluegum eucalyptus," "robusta eucalyptus," and "saligna eucalyptus." These names will be readily understood by botanists and foresters. They undoubtedly will quickly be shortened to "bluegum," robusta," and "saligna" in spoken language and popular writing.

Table 2.--Common names proposed for 81 eucalypts in a provisional checklist[1]

Latin epithet[2]	Common name
alba*	ghost-tree eucalyptus
albens	whitebox eucalyptus
astringens	brown-mallet eucalyptus
baileyana	rough stringybark eucalyptus
baueriana	bluebox eucalyptus
beyeri	Beyer ironbark eucalyptus
bosistoana	coast graybox eucalyptus
botryoides*	bangalay eucalyptus
calophylla	Port Gregory eucalyptus (marri)
camaldulensis (rostrata)	river redgum eucalyptus
campanulata*	stringybark peppermint eucalyptus
camphora	camphor eucalyptus
citriodora	lemon eucalyptus
cladocalyx*	sugar-gum eucalyptus
cloeziana*	gympie messmate eucalyptus
coccifera*	peppermint-gum eucalyptus
consideniana	yertchuk eucalyptus
cornuta	yate eucalyptus
crebra (racemosa)	narrowleaf ironbark eucalyptus
dalrympleana	mountain-gum eucalyptus
deanei	Deane eucalyptus
deglupta*	Amammanit eucalyptus
delegatensis (gigantea)	alpine-ash eucalyptus
diversicolor*	karri eucalyptus
dives	blue peppermint eucalyptus
erythronema	Mt. Lindsay eucalyptus
eximia	yellow bloodwood eucalyptus
exserta	Queensland redgum eucalyptus
fastigata*	brown-barrel eucalyptus
ficifolia	scarlet flowering eucalyptus
fraxinoides	white-ash eucalyptus
globulus	bluegum eucalyptus

NOTE: See footnotes at end of table.

Table 2.--Common names proposed for 81 eucalypts in a provisional checklist[1] — continued

Latin epithet[2]	Common name
gomphocephala	tuart eucalyptus
goniocalyx	mountain graygum eucalyptus
grandis*	rosegum eucalyptus
guilfoylei*	yellow tingle eucalyptus
gummifera (corymbosa)	bloodwood eucalyptus
largiflorens (bicolor)*	blackbox eucalyptus
longifolia*	longleaf woolybutt eucalyptus
macrorryncha	red stringybark eucalyptus
maculata*	spotted-gum eucalyptus
maidenii	Maiden-gum eucalyptus
marginata	jarrah eucalyptus
melliodora*	yellowbox eucalyptus
microcorys	tallowwood eucalyptus
nitens*	shining eucalyptus
obliqua	messmate stringybark eucalyptus
paniculata	gray ironbark eucalyptus
pauciflora	snowgum eucalyptus
pellita*	slatyhide eucalyptus
pilularis	blackbutt eucalyptus
polyanthemos	redbox eucalyptus
populnea (populifolia)	poplarleaf eucalyptus
propinqua*	graygum eucalyptus
pulverulenta*	silverleaf eucalyptus
punctata*	leather-jacket eucalyptus
radiata*	peppermint eucalyptus
regnans	mountain-ash eucalyptus
resinifera	kinogum eucalyptus (redmahogany eucalyptus)
robertsonii*	narrow-leaf peppermint eucalyptus
robusta*	robusta eucalyptus (swamp-mahogany eucalyptus)
rubida	candlebark eucalyptus
rudis	desert eucalyptus
saligna*	saligna eucalyptus (floodedgum eucalyptus)
salmonophloia	salmon eucalyptus
salubris	gimlet eucalyptus
scabra (eugenioides)*	white stringybark eucalyptus
siderophloia	broadleaf ironbark eucalyptus
sideroxylon	red-ironbark eucalyptus
sieberiana	silvertop eucalyptus
stellulata	olive-green eucalyptus
stuartiana (bridgesiana)	apple-box eucalyptus
tessellaris	Moreton-Bay eucalyptus
tereticornis (umbellata)	forest redgum eucalyptus

NOTE: See footnotes at end of table.

Table 2.--Common names proposed for 81 eucalypts in a provisional checklist[1] — continued

Latin epithet[2]	Common name
tetraptera	fourwing eucalyptus
torelliana*	cadagi eucalyptus
torquata	flower coral eucalyptus
triantha (acmenioides)*	triantha eucalyptus
viminalis	manna eucalyptus
wandoo	wandoo eucalyptus
woollsiana	Hanow leaf-box eucalyptus

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[1] Based on Bryan, L. W., and Walker, Clyde M. A provisional checklist of some common native and introduced forest plants in Hawaii. U. S. Forest Serv. Pacific Southwest Forest and Range Expt. Sta. Misc. Paper 69. 36 pp. Berkeley, Calif. 1962.

[2] Species marked with an asterisk are included in the collection at the Waiakea Tree Planting Experimental Area which is described in the section entitled Arboretum.

COMPARISON WITH OTHER TREES

Economically, the native trees of Hawaii do not offer exceptionally serious competition to the more promising eucalypts. Among these native species, only two are both widespread and abundant, koa (Acacia koa) and ohia (Metrosideros collina). Koa grows to rather large size and produces good quality hardwood of high density that has figure and color suitable for furniture, veneer, and handcraft articles. Its form often is poor and per-acre yields are not high. Some foresters suspect that if koa is protected and managed, it may perform better than has been generally assumed from the evidence supplied by mismanaged wild forests. Ohia is very widespread and much more abundant than koa. The wood is objectionably hard and sawing and seasoning are difficult. Owing to poor form, yields are exceedingly low. Many stands of ohia are no more than shrubs.

Introduced trees of other genera offer most of the competition to eucalypts for use in planting, either for wood products or other purposes. A vast number will grow in Hawaii. The forest policy makers of Hawaii are faced by a rather strange but serious dilemma--too many promising species from which to choose! These include trees of such diverse origins and kinds as Tectona, Swietenia, Sequoia, Araucaria, Fraxinus, Acacia, and subtropical and temperate zone species of Pinus.

The utility of various species suitable for Hawaii, both eucalypts and others, has received a fair amount of study. The reports of studies cited in this section are based largely but not wholly upon wood grown in Hawaii and upon the economic situation there.

The smooth-barked tree in the center is a *Eucalyptus saligna*, diameter 23 inches, height 160 feet. Trees with darker bark are *Eucalyptus microcorys*. These eucalypts on Honaunau Forest, Bishop Estate, *Hawaii* are 23 years old.

In 1952 Wold announced the results of testing 36 species including 9 eucalypts. He pointed out that any substantial use in the near future must be based upon *E. robusta* because of the abundance of this species. He ranked it "*fairly easy*" in milling, and "not serious" in checking and warping. In 1958 Wold analyzed eight species, including two natives—koa and ohia—for lumber production. Based upon a total possible score of 60 for various characteristics of growth, log qualities, and lumber qualities, the eight species were scored as follows:

Species	Score
Metrosideros collina (polymorpha) (ohia)	14
Acacia koa (koa)	20
E. robusta	33
E. saligna	31
Grevillea robusta	33
Fraxinus uhdei	34
Toona ciliata var. *australis*	36
Cedrela odorata	35

The high ranking of eucalypts results partly from their large potential yield per acre. High yield is, of course, a widely known characteristic of the genus that has been reported around the world. It is advantageous for reducing logging costs and for maximizing production from the land.

The requirements for timber products in Hawaii have been investigated by Smith (1960). He indicated that climate and construction methods place a premium on strength, appearance, and durability of lumber. For other wood products, requirements are about the same as in other parts of the United States. He pointed out that the Forest Products Laboratory has made good face-grade veneer from E. robusta and that this species is well suited to those applications requiring high strength.

Promising fields for use of sawtimber-size eucalypts in Hawaii lie in plywood and the so-called "factory-type" lumber for cabinet work, furniture, and flooring. Neither now nor in the near future will they be able to compete successfully for structural purposes on a major scale with the abundant, high grade, lighter weight, and easily worked softwoods from the Pacific Coast of North America. At present, small quantities of eucalypts, chiefly E. robusta, are being successfully manufactured and marketed for such products as flooring, furniture wood, wall panels, interior trim, shipping pallets, cross arms for telephone and electricity transmission line poles, and stakes used in irrigation systems.

Physical and mechanical properties of E. robusta and several other woods grown in Hawaii have been studied by the Forest Products Laboratory and described by Youngs (1960). His report provides detailed information on these properties and makes comparisons with properties of other Hawaii-grown woods and United States mainland species. He pointed out that the high shrinkage and interlocked grain of Hawaii-grown E. robusta lead to serious problems in drying.

The Forest Products Laboratory has studied pulping and paper-making qualities of eucalypts in considerable detail, although not with Hawaii-grown wood (1958; Keller, Kingsbury, and Fahey, 1958). From these investigations and experience and research elsewhere the pulping properties of eucalypts are rather well understood. The genus appears to have considerable use for pulp products. But wood pulp is not likely to become a major objective of timber production in Hawaii in the near future. The relatively limited local market could not absorb the whole output of a large, efficient, modern pulp plant. In national and international trade a wood pulp mill in Hawaii probably could not compete with other producers.

In form and strength eucalypts are well adapted for fence posts. Strohman (1957) has reported on wood preservative treatment of eucalypts for this purpose.

The usefulness of Hawaii eucalypts in comparison with other genera for wood products is fairly well understood. Major disadvantages of the eucalypts are weight, hardness, and problems of drying. Major advantages are (a) the presence of a considerable supply of merchantable size material of comparatively uniform size and quality that will continue to increase in the immediate future; (b) good quality of the logs with respect to straightness, diameter, and freedom from limbs; (c) high yields per acre which result in reduced logging costs.

Eucalypts excel many, although not all, other trees in Hawaii in their ability to overtop and quickly outgrow competing vegetation. Silviculturally this is a very important advantage in a climate where many kinds of grasses, lianas, shrubs, and trees spring up quickly on denuded soil. Some species of eucalypts attain heights of 12 to 18 inches within 6 weeks after planting, several feet within 12 months, and more than 10 feet in 24 months. Such trees require relatively little or no weeding if planted on freshly cleared land. Slower starting species may need to be weeded several times. In many instances this rapid, almost explosive juvenile growth undoubtedly has caused eucalypts to be planted in preference to slower starters that produce more valuable wood, such as teak, or that may produce more cubic volume per acre, such as California redwood.

Eucalypts of better commercial utility for lumber are not equally well adapted to all planting sites. For example, on relatively arid exposed tracts on Molokai, certain pines, such as _P. elliottii_ and _P. taeda_, appear more promising, and are favored in the current planting program.

CURRENT FOREST PROGRAM

"Protection of watersheds has been the keystone of Hawaii's forestry program for over 75 years," the Hawaii Forestry Research Planning Committee noted in a report (1960). But during the past decade awareness has been

Eucalyptus robusta logs at the sawmill of Hawaiian Fernwood, Ltd., Hilo, Hawaii.

growing that the Islands have good prospects for producing timber. Bryan reported in 1952 that the Island of Hawaii alone had some 30 million board feet of timber in planted stands, of which more than half were eucalypts (mainly *E. robusta*). He predicted that within a few years about 100 million board feet would be available there.

In 1956 Associate Territorial Forester L. W. Bryan and Myron Wold of Hawaiian Fernwood, Ltd., were sent by the Board of Commissioners of Agriculture and Forestry to New Zealand and Australia to investigate forestry and timber use techniques. Their report described the growth and use of eucalypts and trees of other genera in those countries and noted practices which they believed could be adopted in Hawaii.

Interest has grown rapidly since 1956 and the program of forestation has been accelerated. A good start has been made cooperatively by the Hawaii Forestry Division and the Forest Service to inventory forest resources and to conduct scientific research in wood properties and uses, watershed management, and forest plantation culture.

The Forestry Division has a 5-year planting plan for the Forest Reserves covering the period July 1, 1961 to June 30, 1966. It provides for a program to plant 2,850 acres per year with approximately 1.7 million trees at an average annual cost of $194,000.[2] The plan for a representative year, July 1, 1963 to June 30, 1964, is as shown in the following tabulation:

Island	Number of acres	Number of trees	Cost
Hawaii	1,300	585,000	$ 76,500
Maui	500	291,000	29,000
Molokai	500	427,500	27,000
Kauai	500	350,000	45,000
Oahu	50	29,000	6,000
Total	2,850	1,682,500	183,500

For the entire five-year program 8.4 million trees will be used to afforest 14,250 acres. Approximately 20 percent of the trees, 1.69 million, are eucalypts:

Species	Number
E. saligna	980,000
E. pilularis	150,000
E. paniculata	290,000
E. sideroxylon	140,000
R. robusta	130,000
Total	1,690,000

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[2] In addition, about 300,000 trees per year are to be produced in State nurseries for use on privately conducted tree planting projects.

The recent re-evaluation of the forest planting program, especially the greater emphasis upon timber production, has caused striking changes both in the choice of species of eucalypts and in the number of species to plant. In the earliest private plantings, E. globulus was widely grown. A little later E. robusta was planted extensively by the Forestry Division because it was well adapted to certain habitats where forest cover was wanted. As a result the bulk of the presently merchantable eucalypts are of the latter species. In the new program, E. saligna exceeds the total of all other eucalypts and E. robusta has been reduced to only 8 percent. The Division plans to plant eucalypts mainly on habitats that it does not consider as favorable for more valuable timber species.

The number of species has also been greatly reduced. From July 1, 1956 to June 30, 1959, the Board of Commissioners of Agriculture and Conservation reported that 38 species and 1 variety of eucalypts had been planted on Forest Reserves.[3] Some of these 39 eucalypts were planted in very small numbers for purposes of testing, but the reduction from 39 to 5 is nonetheless significant. Under the new program, the number of kinds to be planted was reduced partly to concentrate upon the more promising timber species and partly to simplify future use.

CULTURE

NURSERY PROPAGATION

Nursery propagation techniques for eucalypts in Hawaii are much the same as those in several other regions of the world and thus require little comment or special explanation. The seeds are sown in small, shallow, wooden trays in sterilized soil which contains a rather high percentage of sand and organic material. Seedlings are transplanted into similar trays at a density of about 30 per square foot when about 6 weeks old. After being shaded for 7 to 10 days, these trays are placed on raised platforms in full sunlight. The trees are ready to field plant within a few months. They are carried to the planting sites in the transplant trays and are removed with small blocks of soil immediately before planting.

Nematoda are sometimes a serious nursery pest. To control them, careful sterilization of the soil by steaming or fumigation is necessary.

In April 1959, Bryan and Carlson tested the bare-root planting of E. saligna. One thousand seedlings were packed in moss and shipped to Honaunau Forest. The roots were treated with a growth hormone (kind not stated), and planted at once. Twenty-five months later, 451 of the trees were alive (45 percent). The tallest one had reached 34 feet in height and the average, 10 feet.

3/ "Forest Reserves" include much privately owned land that the owners have surrendered to the State for a predetermined number of years. This land is exempted from taxation during the term of the agreement.

On December 1, 1960, District Forester Karl H. Korte, Maui, and F. M. Cossitt of the Forest Service started a small experiment in bare-root storage and planting of E. saligna. Transplants, age 5 months, were removed from trays and subjected to four combinations of baling and defoliation treatments and stored at air temperature in a lath house. Portions of the trees from the same trays were left undisturbed in the soil for a check on the usual covered-root method. Half of the stored bare-root trees and check trees were field planted after 7 days and the remainder after 14 days. Survival was counted approximately 4½ months later on May 2, 1961. The following results were reported to this Station:

Treatment	Percent survival[4] Stored 7 days	
	Stored 7 days	Stored 14 days
1. Roots in sphagnum moss and waterproof paper.	87	73
2. Same as #1; leaves removed by hand.	93	47
3. Same as #1; plus tops covered with polyethelene bags.	87	80
4. Same as #3; plus leaves removed.	100	100
5. Check: planted directly from nursery trays in blocks of soil.	93	100

Due to an unusual period of drought the trees had made little or no growth and conclusions could not be made at that time as to the final effect of the treatments. Recently Korte shipped 8,000 E. saligna in polyethelene bags to Honolulu, Oahu. They were reported to have arrived in apparently very good condition.

FIELD PLANTING

The major problem in field planting is to remove competing vegetation. Vegetational cover consists of many kinds and types but in almost all instances rather complete removal is desirable or essential. Although dry periods occur in some areas and may cause competition for soil moisture, vegetation should be removed mainly to eliminate shade and to prevent small trees from being overwhelmed by aggressive grasses and climbing plants. Today the crawler-type tractor with a bulldozer blade has largely replaced earlier methods of clearing. Other types of heavy land clearing and cultivating equipment are also being tried on a limited scale.

The trees are set into holes dug with various types of mattocks and other tools for digging. In the past, trees in forest plantations have been spaced from about 8 x 10 feet to as wide as 10 x 20 feet. For watershed protection wide spacing is satisfactory, but for timber production 10 x 10 feet or 8 x 12 feet should be the maximum. The latter arrangement is generally used because planting production rates are slightly higher when trees are spaced at 8-foot intervals in rows 12 feet apart.

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[4] Basis: 15 trees per treatment.

Planting is possible during most months, but some places are seasonally too wet or too dry. In certain instances planting is scheduled to correspond with periods when agricultural labor is available. For example, on Honaunau Forest of the Bishop Estate trees are planted in May, June, and July, partly because this is a favorable time to plant and partly because a labor surplus exists then (Carlson and Bryan, 1959).

Ordinarily, young eucalypt plantations require no followup care except to exclude browsing animals. In some instances, aggressive vegetation must be removed once.

RELATION TO HABITAT

Based on a great many observations, Bryan (1947) prepared a table that shows his ranking of the vigor of growth of 68 eucalypts in three elevational zones--less than 2,500 feet, 2,500 to 6,000 feet, and over 6,000 feet. Vigor was ranked as "excellent," "good," "fair," "poor," and "dead." Many species were observed only in the lowest elevational zone, and some were seen only in the intermediate or highest zone. Only seven species were recorded in all three zones. Ages of the trees are not shown. Nevertheless, this is a valuable record of adaptability and relative performance.

Recently a more complete evaluation was made of the relationships of elevation, drainage, rainfall, and broad categories of soil for E. saligna, E. resinifera, E. microcorys, E. umbellata, E. deanei, E. viminalis, and E. robusta (Carlson and Bryan, 1959). Although expressed in relatively general terms, descriptions form an additional valuable record for the guidance of foresters.

In 1960 the Forest Service and the Hawaii Forestry Division conducted a detailed study of the growth of E. robusta, E. saligna, Fraxinus uhdei, and Toona ciliata var. australis on the island of Hawaii, (Pickford and LeBarron, 1960). Two 1/10-acre plots were measured for each of the two eucalypt species in eight different plantations, and one additional 1/10-acre plot was taken in each of two additional stands of E. saligna. These plots were located in stands where survival and stocking were moderately good or better in order to determine the potentialities of the trees in the specific habitats. Locations were chosen to sample a wide variety of habitat conditions.

	E. robusta	E. saligna
Elevation (range, in feet)	1,300- 2,400	1,700- 6,600
Annual rainfall (range, in inches)	75- 250	45- 250
Age (range, in years)	23- 38	21- 30
Trees per acre over 10.9" d.b.h. (range, in number)	145- 260	30- 210
Basal area per acre (range, in square feet)	222- 800	114- 365
Height of dominants (range, in feet)	93- 179	89- 174
Mean annual growth (range in feet, board measure)	500- 3,400	500- 3,800

The two eucalypts grew about equally well within the ranges of elevation and rainfall where they were found. Soil depth and soil drainage both appeared to be important though the number of plots was too small and the soil examinations were too superficial to warrant positive conclusions. The ages could not be determined at which maximum yields and highest mean annual growth occurred. The E. saligna trees were somewhat superior to the E. robusta in stem form and natural pruning. In one instance, E. robusta was seen to be aggressively invading an E. saligna stand by seeding. Some of the invaders were at least 40 or 50 feet tall.

Under tropical rain forest conditions E. robusta shows a curious condition on all major islands in Hawaii. Roots start from adventitious buds on the stem at heights of 20 to 40 feet and grow downward, usually through the bark into the soil. The lower stems of occasional E. robusta become completely encased by an interwoven mass of these aerial roots, some of them eight inches in diameter. We have been told that this does not occur in Austalia. Perhaps here is a clue that the species is a relict from a humid, tropical climate in an ancient era when aerial rooting may have been a common habit of growth.

MANAGEMENT AND HARVESTING

Considerable numbers of E. robusta have been harvested on a piecemeal basis for such special products as poles and pilings. Some stands have been cut clean and some have been cut "selectively." These cuttings have not generally been made with a silvicultural control or method in mind. Consequently in this context, "to select" means to remove trees that will serve the purpose of the cutter.

Nevertheless, past cuttings give some clues for future silvicultural management. The stumps sprout prolifically and the new shoots grow rapidly even in lightly cut stands. Some coppice shoots are severely suppressed by the faster growing ones. The weaker ones usually die, but artificial removal of all but the one best sprout per stump would be desirable. The sprouts of E. robusta apparently will provide at least two additional timber crops unless some more shade-tolerant tree becomes established as an understory and effectively bars regrowth of future sprouts. We saw one stand of E. robusta where Podocarpus cupressina had invaded very heavily. As mentioned earlier, we also observed an instance in which E. robusta had invaded E. saligna. Hence, we should anticipate that more shade-tolerant or better-adapted species will sometimes prevail over even very vigorous coppice growth within one or two rotations if seed is available, unless the invaders are eliminated.

A possibly beneficial effect of mixing two species of eucalypts was observed in connection with the growth study made in 1960 (Pickford and LeBarron). In a stand composed of alternate rows of E. saligna and E. resinifera, the E. resinifera had been completely overtopped and none had reached sawtimber size (10.9 inches d.b.h.). They appeared to have served to crowd and prune the E. saligna while the latter trees were making their principal height growth. Eventual suppression of the E. resinifera acted like a natural thinning and left room for the E. saligna to continue growing.

Foresters of the Forestry Division say that the progeny from Hawaii-grown seeds often are hybrids. Almost certainly, wherever crossable eucalypts grow together hybridization will create both problems and opportunities. In either natural seeding or artificial propagation taxonomy may become hopelessly confused in one or two tree generations. The hybrid swarms may contain both superior and inferior types.

COSTS AND RETURNS

The plan for planting and managing the privately owned and administered Honaunau Forest provides the chief source of information on costs and returns from growing eucalypts. This report (Carlson and Bryan, 1959) should be reviewed for a fuller account and explanation. It and limited data about the State planting program are the basis for most of the information in the remainder of this section. Itemized planting costs for portions of the Honaunau Forest where heavy forest cover must be cleared on aa land are:

Item		Cost per acre (1959)
Clearing		$30.00
Planting (spacing 10 x 12 feet; 363 trees per acre)		
Labor (plant 600 trees per man-day at $8)	$4.85	
Foreman (1 per 5 planters at $12)	1.46	
Forester (limited general supervision)	0.54	
Transportation (20 miles per day at $0.20 per mile)	0.48	
Trucking trees from nursery	0.14	
		7.47
Total		[5] $37.47

The costs shown above do not include planting stock because the State provided the trees without charge. Cossitt estimated in 1960 that in a mechanized nursery with an annual production of 4.5 million trees, stock would cost about $11 to $18 per thousand. From the spacing being used on the Honaunau Forest this would amount to roughly $4 to $7 per acre. The present cost of production of stock in the State's several small non-mechanized nurseries is perhaps two to four times as much.

By way of comparison with the cost cited above for the Honaunau Forest, the estimated cost per acre in the State's five-year planting plan is about $65 per acre (Hawaii Forestry Division, 1961). However, the costs at the Honaunau Forest and on the State Forest Reserves probably are not wholly comparable. The State's expenditures include cost of nursery stock and construction of roads to make planting sites accessible. Although roads must be charged to the appropriation for planting, they have permanent value for other purposes. Also, the State will plant almost 600 trees per acre. These differences explain much of the higher outlay. On the other hand a limited amount of prison labor will be supplied, probably at some saving to project funds.

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[5] In May 1961, Carlson revised his estimates upward to a total of $47 per acre. Principal changes resulted from reducing spacing to 10 x 10 feet (426 trees per acre) and adding a road construction cost of $5 per acre.

The management plan for the Honaunau Forest estimates yields for *E. robusta* and *E. saligna* at 40,000 to 80,000 board feet per acre at 30 years conservatively. Assuming conservatively that the rotation is 35 years and that present stumpage value will be $20 per thousand board feet, then earnings per acre for deep soils and aa land were calculated as follows:

Investment in planting ($38 at 5 percent interest)	$ 210
Yield (60,000 board feet at $20 per thousand)	1,200
Gross profit for 35 years[6]	990
Gross profit per year	28

Under the same conditions profits for *Fraxinus uhdei* and *Toona ciliata* var. *australis* were estimated at $35 and $39 per acre per year.

Estimates of yields and gross profits from eucalypts were also made for two other site conditions, one amounting to $30 per acre per year; the other, $19.

The management plan suggested that costs would decline and net earnings would increase after the first rotation because the stands would reproduce by sprouting.

RESEARCH

In 1957, the Hawaii Department of Agriculture and Conservation and the Forest Service entered into a cooperative agreement on forest research. Scientific direction is supplied by the Forest Service; both organizations furnish employees; and the State has taken an active part in the selection of subjects to study. This arrangement makes the services of this Station and the Forest Products Laboratory available to Hawaii. Both State and Federal agencies contribute to the financing and conduct of the research program. A research center under the direction of R. E. Nelson was established at Honolulu by this Station in 1958.

FOREST SURVEY

The first and, to date, the largest undertaking has been an inventory of forest resources. From two to four foresters have been engaged on this project. Determination of acreage of wildlands, vegetational cover types, and timber volume and growth are major primary objectives. An

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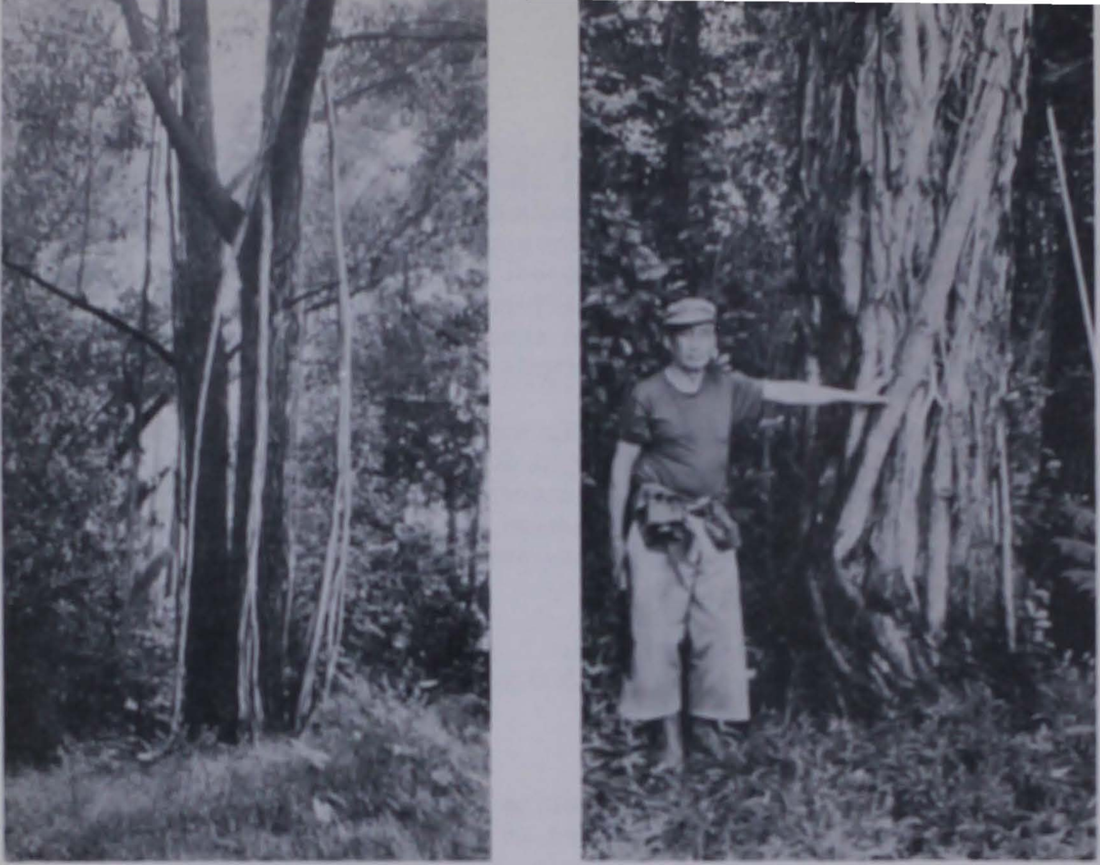
[6] Taxes and costs of administration have not been deducted from gross profit.



Aerial roots are a remarkable condition manifested by Eucalyptus robusta in Hawaii. They can extend to the ground separate from the tree trunk, as shown above left. These roots can also encase the tree trunk, as shown above right.

important adjunct to the survey is the preparation of tables to measure the cubic- and board-foot contents of timber. This survey is now almost completed. When finished it will provide more accurate estimates of the acreage, volume, and quality of eucalypt forests than are now available. It will also provide volume tables specially designed for the locally grown eucalypt trees.

SILVICULTURE

One forest scientist was engaged full time on silvicultural research during 1960 and 1961. In 1962 the number was increased to three. In addition other scientists are assigned temporarily from time to time.

A few miles from Hilo at an elevation of 800 feet test plantings of many genera and species of trees have been made at the Waiakea Tree Planting Experimental Area by the Hawaii Forestry Division. Thirty eucalypts are included, of which 28 are identified by an asterisk (*) in the provisional checklist (table 2). The other two are E. salicifolia (amygdalina) and another identified only by the lot number of the collection, "11309."

The eucalypts in this arboretum were planted between August 1957 and July 1960. They are spaced 10 feet by 10 feet, and numbers range from 10 to 364 per species. Most of them are arranged in rows of 10 and generally all trees of one species are located in one or two groups. Additional trees may be planted.

The records and maps of this experimental area are quite complete. For example, they have been used to show the growth at age two years of some faster growing species and the species that did not attain an average height of 5 feet at that age (table 3). Eucalypts are well represented among the fast starters, but some of them also are included among the species that grew slowly during the first two years after outplanting.

In 1961 several small permanent growth plots were established in various locations on the Island of Hawaii for periodic remeasurement. These will supply the first information on periodic growth to guide forest managers in determining the proper time to harvest for maximum yield. The plots will also supply information on stand structure and plant succession. _E. pilularis_, _E. saligna_, _E. resinifera_, and _E. robusta_ were included among the species sampled. Admittedly, the few plots that were established will supply only limited information. Ultimately many growth plots must be installed. A few spacing studies also were established to determine optimum initial stocking. For eucalypts the spacings to be tried are 8, 10, 12, and 16 feet. An experiment was also made with a mechanical tree planter on saligna eucalyptus on Molokai. Preliminary results were satisfactory. These tests may or may not include eucalypts.

Probably almost all of the eucalypts which have good potential for wood production are already present in Hawaii. However, a vast array of possibilities exists for research in genetics in the areas of hybridization, provenience, and selection of superior genotypes.

Silvicultural control of wood quality is an unexplored field. Site adaptability needs much more study. Soil deficiencies, soil depletion, and soil amendments have not been studied with respect to eucalypts and other trees. These opportunities for research greatly exceed the possibilities for finding answers quickly unless the research program is greatly accelerated.

PROTECTION

Grazing and forest fires present no serious problems today. Nor are serious parasites known to be present in growing forests. Quarantine regulations on importations are strict and well enforced, but no one knows when some serious parasite of eucalypts may slip in. As mentioned earlier, wind damage may become more severe when harvesting increases.

WOOD USES

Undoubtedly, more attention could and should be given to the study of wood properties. More urgent problems are milling and seasoning practices, development of products that are best suited to the local economic structure, and wood preservation. In this warm humid climate, termites, boring insects, and,decay organisms destroy logs and many manufactured products. A products research specialist has been assigned by the Forest Service as part of the cooperative program with the Forestry Division to conduct local studies and maintain contact with the Forest Products Laboratory.

Table 3.--Size of some trees in the Waiakea Tree Planting Experimental Area two years after outplanting[1]

Species	Average height	Average d.b.h.	Maximum height
	Feet	Inches	Feet
Species that reached average height of 10 feet			
Casuarina cunninghamiana	15.8	3	27
Casuarina nodifolia	13.0	1 1/2	20
Eucalyptus botryoides	22.4	5 1/2	37
Eucalyptus cloeziana	12.8	1 3/4	15
Eucalyptus deglupta	17	5	27
Eucalyptus grandis	18.1	4 3/4	37
Eucalyptus pellita	14.9	4	27
Eucalyptus punctata	15.6	3 3/4	30
Eucalyptus radiata	15	3 1/2	26
Eucalyptus robusta	15.2	4 1/2	28
Eucalyptus rubida	15.5	3	27
Eucalyptus saligna	18.9	4 1/2	35
Toona ciliata var. *australis*	11.6	4	39
Species that reached average height of 5 feet or less			
Araucaria excelsa	3	1/2	7
Araucaria angustifolia	3.4	1/2	5
Callitris macleyana	1.24	--	3
Castanosperma australe	1.7	1/4	4
Cedrela odorata	2.6	2 1/2	10
Chamaecyparis lawsoniana	4	3/4	5
Eucalyptus largiflorens (bicolor)	4.8	1/4	8
Eucalyptus coccifera	3.8	1/4	7
Eucalyptus fastigata	2.9	1/2	6
Eucalyptus robertsonii	3	1/4	5
Eucalyptus sp. #11,309	2.8	1	10
Flindersia ifflaiana	1.9	3/4	9
Pinus palustris	1	--	1
Pinus taeda	3	1/2	4
Tectona grandis	4	1/2	12

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[1] Unpublished manuscript by L. W. Bryan, undated, copy on file, Pacific Southwest Forest and Range Experiment Station, Berkeley, Calif.

WATERSHED MANAGEMENT

Protection of the water supply for agricultural, industrial, and domestic use is still a matter of great concern to the public and to State officials. Two scientists are now working on problems of hydrology in forests. They seek to learn how the production of usable water can be maximized. The problem partly is to insure recharging of underground water supplies; partly it is to insure delivery at surface streams and catchments. The watershed research program is interested in such aspects of forest hydrology as (a) fog drip, (b) interception of rain by vegetation, (c) use of soil moisture by vegetation, (d) water infiltration into the soil and how it is affected by vegetational cover and by logging and other land uses, and (e) causes and prevention of soil erosion. The first studies deal with soil compaction and the depletion of soil moisture by several kinds of plant cover, including eucalypts.

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MISCELLANEOUS PAPER No. 65
JANUARY 1962

FIRE WEATHER SEVERITY FOR SOUTHERN CALIFORNIA IN 1961

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ARTHUR R. PIRSKO

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FIRE WEATHER SEVERITY FOR SOUTHERN CALIFORNIA IN 1961

By
C. M. Countryman and Arthur R. Pirsko

In 1959 California experienced one of its most disastrous fire years of recent history. Deficient spring precipitation, a hot, dry summer, and unusually frequent föehn type winds with their extremely low humidities and high speeds combined to make the season a nightmare for the firefighting forces. When the first winter rains fell, firefighters relaxed and looked forward to an easier season in 1960. California had never experienced two bad seasons statewide in succession; there was no reason to expect any change now.

But the 1960 season was not easier. The same pattern of weather that occurred in 1959 began to appear early in the spring, and by the end of the 1960 season California had gone through a season with even worse burning conditions than 1959.

Then, for the third season in a row, the familiar weather pattern began to develop in the spring of 1961. Fire control agencies quickly realized that the potential for fire losses in 1961 could easily surpass anything before experienced. They began hurriedly to bolster their firefighting capacity and to warn the public of the potential danger. The danger materialized, and this is a report of the conditions that firefighters had to contend with in 1961.

Fire Weather Severity

New indexes in the California fire danger rating system provide a convenient means of getting a quantitative measure of the fire weather for any time period desired. The rating system now includes five basic indexes:

Spread Index--a measure of how fast a fire will spread.
Intensity Index--a measure of how hot a fire will burn.
The Ignition Index--a measure of the ignition potential of a firebrand and also the spotting potential of a fire.
Burning Index--a combination of intensity and spread indexes which gives a measure of the potential control job of an individual fire.
Fire Load Index--a combination of ignition and burning indexes which gives a measure of the total potential control job that the fire control organization may face.

The fire weather severity can be measured simply by cumulating the fire load index for the desired period.

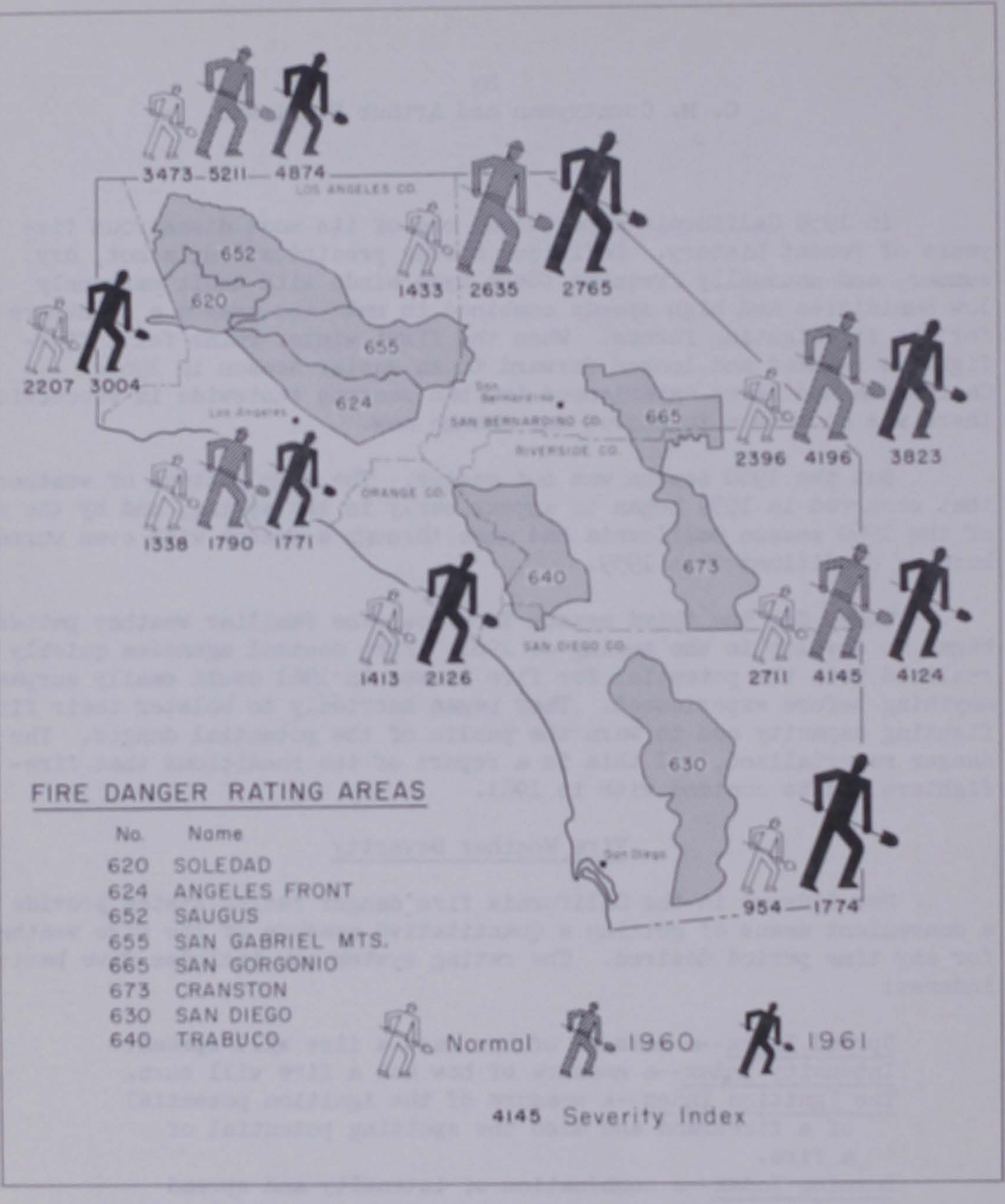
3473
5211
4874
LOS ANGELES CO.
652
620
655
624
2207
3004
Los Angeles
1338
1790
1771
1433
2635
2765
San Bernardino
SAN BERNARDINO CO.
RIVERSIDE CO.
665
2396
4196
3823
ORANGE CO.
640
673
1413
2126
SAN DIEGO CO.
2711
4145
4124
630
San Diego
954
1774
FIRE DANGER RATING AREAS
No. Name
620 SOLEDAD
624 ANGELES FRONT
652 SAUGUS
655 SAN GABRIEL MTS.
665 SAN GORGONIO
673 CRANSTON
630 SAN DIEGO
640 TRABUCO
Normal
1960
1961
4145 Severity Index

Figure 1.--Southern California fire weather severity, June 1 - October 31.

Representative fire danger rating areas were selected over southern California, and the fire load index was cumulated for these areas for the period of June 1 to October 31. In most areas the 1960 and 1961 seasons were of about equal severity for the entire period (fig. 1). Some areas were a little worse in 1961 than in 1960, some a little better. In each area, though, the seasonal severity far exceeded normal both years. The severe conditions were reflected in the severe fire behavior both years.

To show trends in the severity of the fire weather during the fire season, the severity index was computed by five-day periods for one sample area, and the departure of the index from normal for each period was determined. Five of the thirty 5-day periods had averages of normal or below (fig. 2). The others varied from slightly more than normal to much above normal. For example, from June 15 to 20, the index averaged 26; this is 23 points above the 3-point normal index for that period, or almost 9 times normal. Severe periods were experienced in June, early July, part of September, and October. The fire weather during the first 5 days in October, when the index averaged 30.2 points above the normal index of 10 for that period was particularly severe.

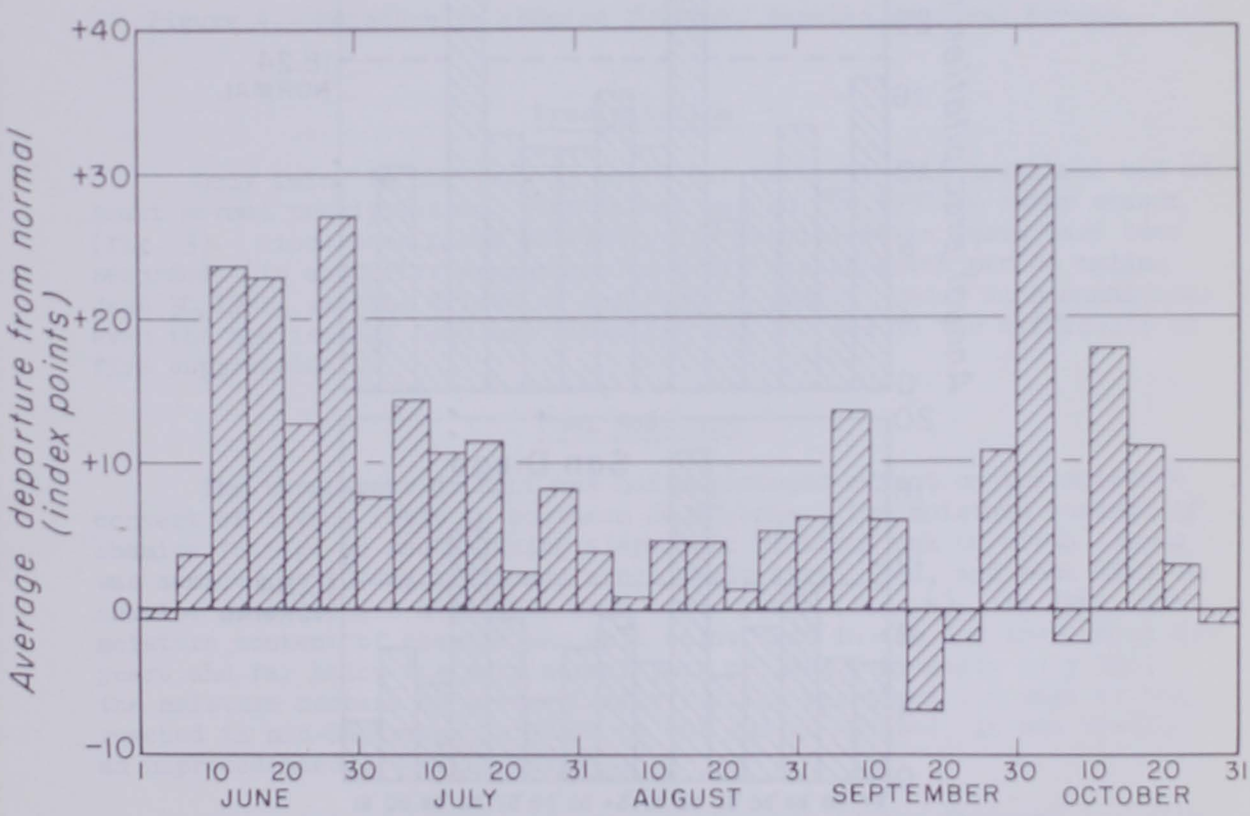

Figure 2.--Departure from normal of fire weather severity for Area 655, San Gabriel Mountains, in 1961.

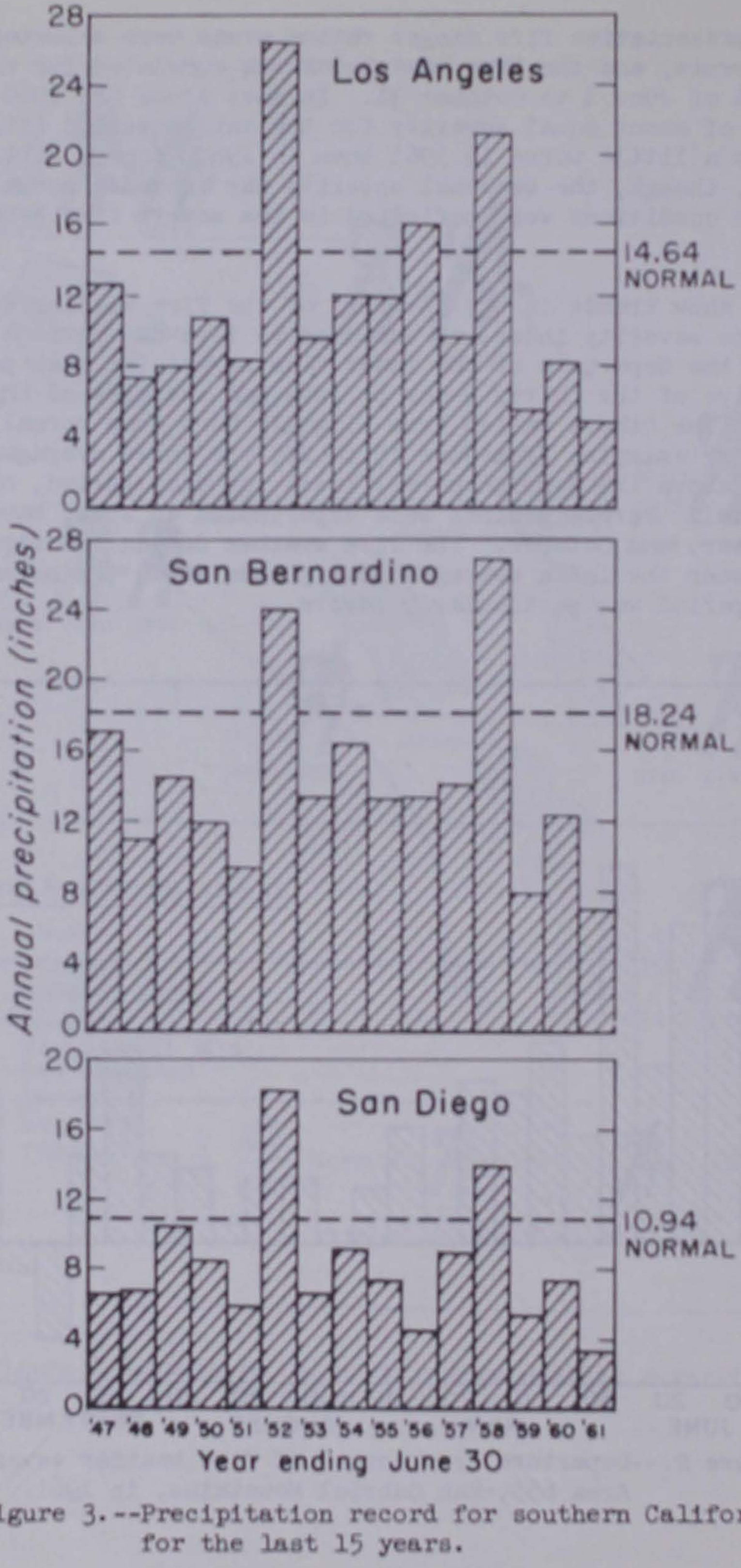

Figure 3.--Precipitation record for southern California for the last 15 years.

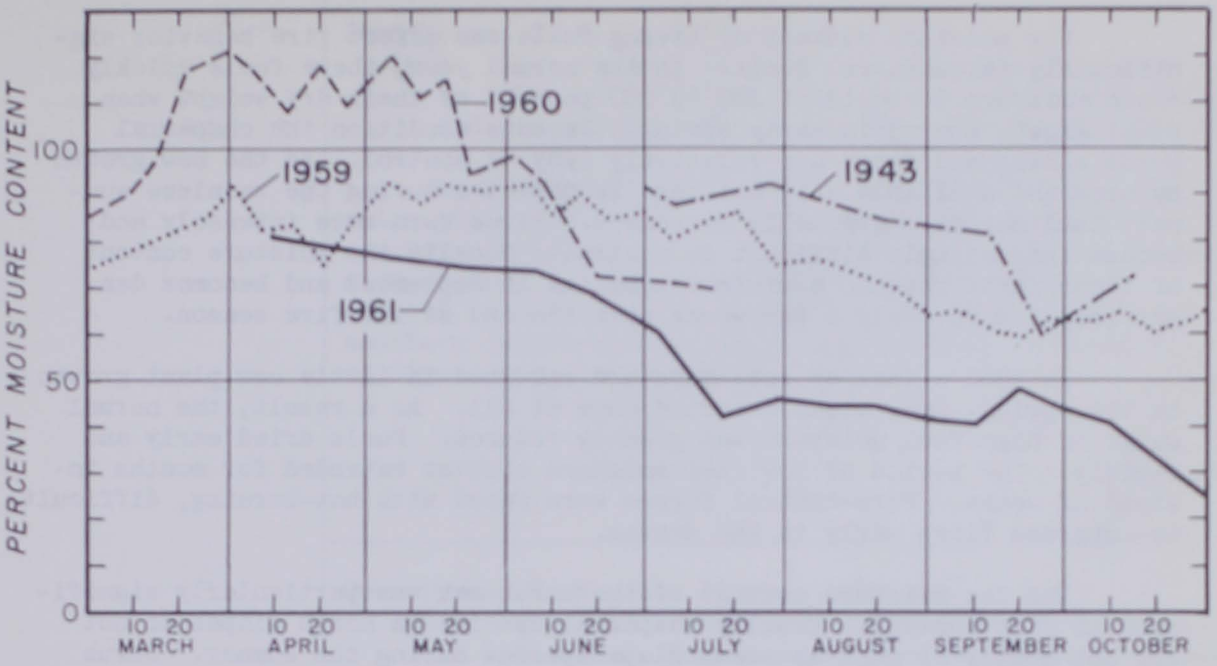

Figure 4.--Moisture in chamise foliage, Angeles National Forest.

Precipitation

Only twice in the past 15 years has the semi-arid southland had at least normal precipitation. The latest was in the 1957-58 rainy season (fig. 3). Since then three extremely low precipitation years have been recorded. In most fire danger rating areas the 12-month period ending June 30, 1961, was the driest of the past 15 years. Under such conditions even the heaviest of dead materials dry out and add to the difficulty of fire suppression.

Fuel Moisture

The three-year drought has had a profound effect on the moisture content of living fuels in southern California. The moisture content of chamise foliage on south-facing slopes and of scrub oak on north slopes was sampled at 10-day intervals since early April 1961, and some data on chamise moisture are available from other years (fig. 4). In 1961, the moisture content of chamise was well below that in the two preceeding dry years and far below the more normal year of 1943. By early July 1961, the moisture content of green chamise foliage was about the same as that reached in mid-September in 1959; by the end of October, it had reached an unprecedented low of 26 percent.

The moisture content of the oak on north slopes followed a similar trend. It reached a minimum of 35 percent by the end of October.

Low moisture content of living fuels can affect fire behavior significantly in chaparral fuels. In the normal year, these fuels quickly reach moisture contents of 160 to 200 percent of their dry weight when plant growth starts in early spring. In this condition the chaparral burns slowly and fires are relatively easy to control. As the new growth matures and available soil moisture is depleted during the rainless summer, fuel moisture gradually decreases. Fires burn more intensely and become increasingly difficult to control. Usually the moisture content of these fuels reaches a minimum sometime in September and becomes dangerously low for only a few weeks near the end of the fire season.

In 1961 a lack of soil moisture resulted in little new plant growth in the spring; many areas reported none at all. As a result, the normal surge of high fuel moisture was greatly reduced. Fuels dried early and rapidly. The period of low fuel moisture content extended for months instead of weeks. Fire-control forces were faced with hot-burning, difficult-to-suppress fires early in the season.

The low moisture content of the scrub oak was particularly significant in fire control. Usually chaparral species on north slopes do not dry out nearly as much as south slope species during the summer. Scrub oak, for example, normally reaches a minimum moisture content of 100 to 125 percent in the fall. Fires starting or burning into north slopes do not have the high intensity of south-slope fires. Fire-control strategy is frequently aimed at taking advantage of this difference in burning conditions between north and south slopes. In 1961, however, the north-slope oak fuel was nearly as dry as the south-slope chamise. Firefighters could no longer steer fires to north slopes and expect easier control--north slopes burned as hot as south slopes.

Three years of insufficient moisture has also taken its toll of living plants. The amount of dead and dying chaparral showed a marked increase in 1961. Sometimes parts of the plant have died; sometimes whole plants or groups of plants. The full extent of the tissue dieback will not be known until spring when new growth emerges. It is certain, however, that for southern California as a whole the amount of dead, and potentially highly flammable, fuels in the chaparral has been greatly increased. This increase in dead fuels can be expected to result in more-intense, difficult-to-suppress fires long after the living fuel moisture returns to its normal pattern.

Countryman, C. M., and Pirsko, Arthur R.
1961. Fire weather severity for southern California in 1961. U.S. Forest Serv. Pacific Southwest Forest and Range Expt. Sta. Misc. Paper 65. 6 pp., illus.

Long drought, severe daily fire weather, and extraordinarily dry fuels combined in 1961 to present southern California fire-control agencies with the worst fire-control job in recent history. The cumulative effects of the drought on the fuel charactistics of the southern California chaparral may increase difficulty of fire control for years to come.

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Miscellaneous Paper No. 66 1962
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Compiled by
Lucille M. Tichenor

The 221 articles in this publication are the results of research work done at the Institute of Forest Genetics, Placerville, California, by staff members and visitors from all parts of the world. The names of staff members are underlined.

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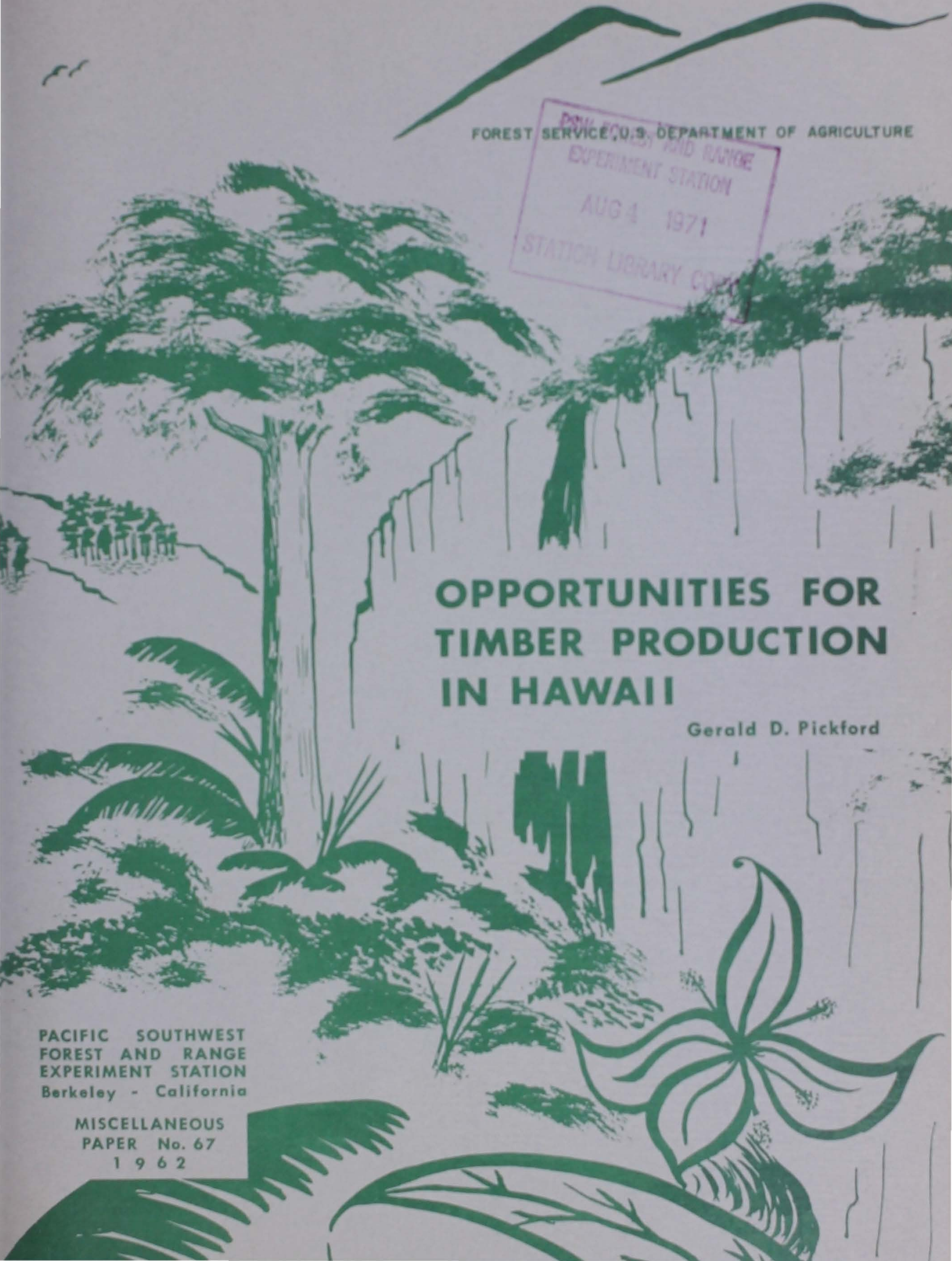

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OPPORTUNITIES FOR TIMBER PRODUCTION IN HAWAII

Gerald D. Pickford

PACIFIC SOUTHWEST
FOREST AND RANGE
EXPERIMENT STATION
Berkeley - California

MISCELLANEOUS
PAPER No. 67
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By

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Forest Ecologist

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Presented at the Tenth Pacific Science Congress of the Pacific Science Association, held at the University of Hawaii, Honolulu, Hawaii, U.S.A., 21 August to 6 September, 1961, and sponsored by the National Academy of Sciences, Bernice Pauahi Bishop Museum, and the University of Hawaii.

Miscellaneous Paper No. 67 1962
U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
Berkeley, California

OPPORTUNITIES FOR TIMBER PRODUCTION IN HAWAII[1]

By
Gerald D. Pickford[2]

If you reviewed lumber production statistics for Hawaii you might assume that this State has little or no forest resource. Hawaii imports 100 million board feet of wood products each year and produces less than 1 percent of its needs from its own forests. Yet, half of Hawaii is timbered or brush-covered. More than a million acres--one-fourth of the State's land area--are suited to commercial timber production.

Hawaii's population of 633,000 is four times greater than in 1900. It is expected to rise another 20 percent by 1975. By then, Hawaii's 7 inhabited islands will be crowded with 120 people per square mile. If these residents are to enjoy high social and economic standards, Hawaii's natural resources must be fully and wisely used. A renewable resource, such as timber, could be raised to a much higher level of production by planting and silvicultural practices. Furthermore, local processing of timber products from Hawaii's forests can add greatly to the State's economic wealth. Had the 100 million board beet of timber used in Hawaii in 1960 been grown and manufactured within the State, it would have provided 1,000 full-time forest industry jobs there.

Early Forest Policy

Timber from Hawaii's forests does not now contribute importantly to the State's economy for several reasons. Perhaps the chief one is that Hawaii did not establish its 1.2 million acres of Forest Reserves back in 1905 primarily to provide timber. It established the reserves to avert a critical water shortage. Usable water for growing and milling Hawaii's chief product, sugar cane, was then decreasing alarmingly as the result of serious floods and heavy soil erosion. This flooding and erosion accompanied widespread forest destruction that had been caused by a century of severe overgrazing from wild cattle, sheep, and goats. Domestic cattle that roamed at large and crowded into the forests wherever they could find forage and water also effected damage, as did uncontrolled fires set accidentally or to clear land for crops or pasture. Consequently, for more than 50 years after 1905, watershed protection was the keynote of management on Hawaii's Forest Reserves. Protection was given to a degree that the territory permitted no disturbance of forest cover by man or beast. The program of total forest protection contributed to more stable and more usable water supplies for Hawaii, but it prevented any use of the State Forest Reserves for timber production.

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[1] Presented at Symposium on Forest Growth Studies, Tenth Pacific Science Congress, Honolulu, Hawaii, August 29, 1961.

[2] Hawaii Department of Land and Natural Resources, Division of Forestry, in cooperation with Pacific Southwest Forest and Range Expt. Sta.

A second deterrent to local forest industry is the poor quality of timber produced by the native Hawaiian forests. The most abundant species, ohia-lehua (Metrosideros polymorpha) is poorly suited to lumbering because of its meager growth form and undesirable wood properties. Overgrazing easily kills koa (Acacia koa), the only native tree that is commercially valuable. The severe overgrazing prior to establishing the Forest Reserves destroyed the commercial koa stands except for a few thousand acres scattered on the slopes of Mauna Loa and Hualalai.

Hawaii exported sandalwood (Santalum spp.) in important quantities to India and China from 1810 to 1850. By 1860 the trade in this delicately scented wood had practically ceased because Hawaii's supplies were exhausted from overcutting. Sandalwood has not regenerated abundantly, nor has enough demand developed for it to warrant replanting for wood production.

The difficulty and expense involved in clearing away dense jungle so that valuable timber species can be planted have been a third major drawback to forest industrial development in Hawaii. The forest lands of the State generally lie in the heavy rain belt on mountainsides above the settlements. Soils, though productive for timber, are often almost unbelievably rocky. Jungle vegetation is dense and difficult to clear. Wet, swampy conditions are common on the more level sites. Heavy crawler-type tractors with bulldozers and other specialized equipment suitable to operate effectively under these difficult conditions have not been available very long--20 to 25 years at most. Landowners and public agencies only recently have started fairly large-scale land clearing operations with mechanized equipment to convert the jungle into residential areas, improved pastures, and forests.

Public awareness of the important timber-producing potential of Hawaii's forest land began only about 10 or 15 years ago. For example, an 80-page report (Bryan 1947) sponsored by the Hawaii Division of Forestry and published in 1947 did not mention the words "timber" or "lumber" or "forest industry" as it summarized 25 years of forestry and watershed protection on the island of Hawaii and described results on experimental plantings of more than 1,300 exotic tree and shrub species within the Forest Reserves. However, in 1952 the author of the 1947 publication again wrote on forestry, this time in the Biennial Report of the Board of Commissioners of Agriculture and Forestry on the subject of "Timber Qualities of Some Exotic Timber Trees in Hawaii" (Bryan 1952). He stated that about 100 million board feet of timber would be available for harvest by 1960 from planted stands in the Forest Reserves on the island of Hawaii. The policy of complete protection to forest cover in the Forest Reserves was beginning to be questioned.

The voice of Hawaii's forest industry was first heard in the Board of Commissioners of Agriculture and Forestry Biennial Report of 1952 (Wold 1952). This report included ratings on the lumber manufacturing qualities of 36 Hawaiian-grown trees that had been tested in a sawmill in Hilo on the island of Hawaii. The tests were entirely on exotic trees. The report pointed out that any timber utilization in the near future would have to rely heavily on *Eucalyptus robusta* because of the relative abundance of that species in the Forest Reserve plantations. The report did not consider ohia and koa commercially exploitable for lumber.

In 1956, the Board of Commissioners of Agriculture and Forestry sent a forester and a lumber manufacturer to Australia and New Zealand to investigate forest management and timber utilization techniques there. Many tree species from these two countries have been introduced in Hawaii. The report of the two men contains much valuable information on which to base an expanded forestry program. It has also served to quicken the growing interest in forestry within Hawaii (Bryan and Wold 1957).

The Timber Potential

Realizing that Hawaii has a forest resource that, if developed, will add significantly to its economy, the 1957 Territorial Legislature passed forestry legislation authorizing the Forestry Division to establish a forest research program in cooperation with the U.S. Forest Service. One major object of the program is to determine how best to develop sustained timber production and utilization on Hawaii's forest lands. Hawaii's legislature has shown continuing and growing interest in forestry since 1957 by annually appropriating funds to support the cooperative research program, and also by appropriating money to clear noncommercial tree and shrub cover from lands within the Forest Reserves and plant them to timber trees. The 1961 legislative session appropriated funds to build a centralized tree nursery that will provide planting stock at reasonable cost to the Forest Reserves throughout the State. In 1961, the Forestry Division prepared a planting plan for the Forest Reserves for the period July 1, 1961, to June 30, 1966, to plant 2,850 acres per year with about 1,700,000 trees at an average cost of $68 per acre. Costs of fairly large-scale clearing and planting operations on the Honaunau Forest run from about $40 to $55 per acre. Therefore, the estimated cost of nearly one million dollars for the 5-year program seems entirely realistic.

In 1959, the Honolulu Chamber of Commerce and the Hawaii Department of Agriculture and Conservation conferred on Hawaii's timber potential. This meeting stressed: (1) the early completion of the Hawaii forest resource survey started in 1958 under the cooperative research program, (2) the compilation of available information on tree species adaptability from past tree plantings in the State, and (3) an intensive study of utilization potentials and future markets. As an outgrowth of this conference, several forestry research planning committees were staffed by members of the Chamber of Commerce, the U.S. Forest Service, the Board of Agriculture and Conservation, and the State Division of Forestry. Scientists of the University of Hawaii, members of the Soil Conservation Service, and the State Legislature and others interested in the future of Hawaiian forestry assisted in the committee work. The result of this effort has been a Wildland

Research Plan for Hawaii that summarizes the forest land situation in Hawaii and charts a course for immediate and long-term research in the development of Hawaii's wildland resources, including water, timber, grazing, recreation, and wildlife (Hawaii Department of Agriculture and Conservation 1960). Important in this research program is the problem of developing planted forests in Hawaii.

Preliminary studies of Hawaii's timber potentials indicate that future production must come primarily from planted, introduced species. Further, it is estimated that Hawaii's Forest Reserves contain about 400,000 acres that are suitable for timber planting. If average annual growth amounts to 500 board feet--a very conservative estimate for Hawaii's growing conditions--the State can look forward to producing 200 million board feet of timber per year, twice its present consumption. Considerable time must pass after the timber production program begins before the full annual growth can be harvested. Tentatively the rotation is estimated to be 40 years. Of course, considerable acreages of timber are merchantable already, and additional amounts will mature every year. However, past plantings were on a much smaller scale than is visualized for the new program.

Data from Hawaii's forest survey, although incomplete, indicate that the State has about 52,000 acres of tree plantations. These were planted largely for watershed protection and mostly between 1930 and 1940. Some 19,000 acres are growing trees such as paper-bark (Melaleuca leucadendron), casaurinas (Casaurina spp.), and bluegum eucalypt (Eucalyptus globus) that are virtually worthless for timber. But the remaining 33,000 acres are producing substantial quantities of commercial timber. About 27,000 acres are growing species of marketable eucalypts, primarily robusta eucalypt (E. robusta). An additional 6,000 acres are planted to such timber species as tropical ash (Fraxinus uhdei), Australian toon (Toona ciliata var. australis), silk-oak (Grevillea robusta), and Norfold-Island-pine (Araucaria excelsa). Some of these plantations are already between 30 to 40 years old. Most of them are over 20 years and have some trees of merchantable size. Therefore, it appears that Hawaii can start cutting planted timber stands at the rate of about 800 acres per year, and if yields average 20,000 board feet per acre, could sustain an annual cut of 16 million board feet.

Several investigations of timber yields in Hawaii indicate that the State can now sustain a timber industry considerably larger than 16 million board feet per year. Measurements of plantings in the Honaunau Forest on the island of Hawaii in 1957 (Carlson and Bryan 1959) show board-foot yields of 28-year-old tropical ash to be 32,000 per acre; of 22-year-old Australian toon, 23,000 per acre; of 30-year-old redwood (Sequoia sempervirens) 33,000 per acre; of 25-year-old kinogum eucalypt (E. resinifera) 36,000 per acre. A 40-45 year old stand of robusta eucalypt on Maui cruised in 1960 had a volume of 66,000 board feet per acre. A yield study conducted in 1960 on the island of Hawaii (Pickford and LeBarron 1960) measured per-acre volumes of 60,000 board feet from 8 stands of robusta eucalypt that averaged 31 years old; 52,000 board exotic trees. The report pointed out that any timber utilization in the near future would have to rely heavily on Eucalyptus robusta because of the relative abundance of that species in the Forest Reserve plantations. The report did not consider ohia and koa commercially exploitable for lumber.

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Eucalyptus saligna is one of Hawaii's fastest growing trees. This stand, planted on the Hamakua Forest Reserve in 1939 has trees nearly 200 feet tall and has grown sawtimber at the annual rate of 3,200 board feet per acre since the year it was planted. In 1960 the stand had produced a total yield of 68,000 board feet of sawtimber per acre.

Toona ciliata var. australis is one of the most promising timber trees for Hawaii. These 5-year-old trees in the Waiakea Forest Reserve have reached a maximum height of 46 feet and a maximum diameter breast height of 7.2 inches.

Queensland maple (*Flindersia brayleyana*) is a hardwood highly valued in world lumber trade. These 3-year-old trees in the Waiakea Forest Reserve, Hawaii, are 25 to 30 feet tall and nearly 5 inches in diameter.

Loblolly pine (*Pinus taeda*) grows rapidly on the island of Molokai. These young trees planted on the land of Kaunakakai in 1957 exhibit great thrift and vigor. They averaged 14 feet tall in November 1961.

feet from 10 stands of saligna eucalypt (E. saligna) that averaged 24 years old; 17,000 board feet from 9 Australian toon stands that averaged 31 years old; and 14,000 board feet from 12 tropical ash stands that averaged 30 years old.

The yield study disclosed some rather startling growth rates of individual trees and stands. A dominant kinogum eucalypt tree in the Hamakua Forest Reserve on the island of Hawaii at 27 years stood 203 feet tall, measured 25.3 inches in diameter at breast height, and contained 1,760 board feet of sawtimber. One saligna eucalypt stand measured in the Hamakua Reserve had averaged 8 feet of height growth per year during its 21 years. Another 21-year-old saligna stand in the Hamakua Reserve had grown sawtimber at the rate of 3,800 board feet per acre per year. Still another robusta eucalypt stand in the Hilo Reserve on the island of Hawaii had produced 130,000 board feet of sawtimber per acre in its 38 years. The yield study statistics were measured on plots selected for full stocking as nearly as possible. Hence, they indicate growth potential and should not be regarded as representative samples of the stands.

If we consider that half of Hawaii's timber plantations are fast-growing eucalypts and that more than 40 percent are robusta eucalypt which certainly promises to yield more than 40,000 board feet per acre at 40 years, we can see that Hawaii is now producing timber at a rate that exceeds 16 million board feet annually. Perhaps the growth rate, and the sustained timber production, comes closer to 30 million board feet per year.

Reliance on Hardwoods

Hawaii has wisely chosen to favor hardwood species in the planting program on the Forest Reserves, except for relatively arid, exposed sites where certain conifers, such as loblolly pine (Pinus taeda) and slash pine (P. elliottii) have shown promise. With its relatively small total production, Hawaii cannot expect to compete with large softwood exporters such as the northwestern United States. But if Hawaii raises fine tropical hardwoods for export, it can definitely compete in world markets. The world trade seldom has an oversupply of quality hardwoods.

Which hardwoods to choose for the expanded planting program is an important problem facing Hawaii's foresters today. With only 400,000 acres of potential forest plantations within the State Forest Reserves in the picture at present, good manufacturing and marketing practices call rather emphatically for planting as few species as possible. Therefore, it is highly important that foresters select the best suited, most valuable species early in the game. Tropical ash, Australian toon, and Queensland-maple (Flindersia brayleyana) are three high-quality hardwoods that have proved adaptable to Hawaii. They are being planted in substantial amounts in the new program. But what of many others of the world's fine hardwoods? Some of these, like primavera (Tabebuia donnell-smithii) and yellow-poinciana (Peltophorum inerme) can be found growing luxuriantly as isolated specimens in Hawaii. Perhaps some can be found that will out-yield or yield more valuable wood than the species now being planted.

Determining what are the best or the most suitable kinds of trees for the various sites in Hawaiian forests is a research problem of first priority. A closely related problem in the planting program concerns the selection and development of superior strains in the species that are chosen as the best for planting.

Still other problems which, if resolved, will aid Hawaii in obtaining the most and highest quality production from its planted forest stands are: What is the best way to collect and store tree seeds under Hawaii's tropical conditions? What is the best and cheapest method of producing nursery stock in quantity under Hawaiian conditions? What are effective and practical techniques to prepare sites for artificial and natural regeneration on the various kinds of areas where site preparation is needed? What are the best and most practicable methods for planting and seeding and for tending the trees while they are becoming established? Are pure or mixed species forests more desirable? What is the optimum stocking for various species on various sites and for different products? What are desirable rotation ages for the various species on various soils and for different products? Many more questions connected with establishing Hawaii's future forests need answers, but these are considered to be some of the most urgent.

One encouraging feature of forest regeneration has been observed on cleared forest land in Hawaii. It is the dense stand of thrifty koa reproduction that sometimes follows bulldozing on areas still containing relicts of the old koa forest. This reproduction evidently stems from seed stored in the soil. The existing seed trees appear to be too widely scattered to produce the dense, even-aged stand of seedlings from seedfall. On the Honaunau Forest for example, koa reproduction equals or overtops 2-year-old stands of tropical ash that had been planted immediately after the native forest had been removed by bulldozing. Koa reproduction has been noted in many other places on the island of Hawaii, where the forest cover has been disturbed by road building or pasture improvement. It may be that exposing the mineral soil and removing competition by the ohia trees and dense shrub growth favors the natural regeneration of this valuable hardwood species. Since attempts to reproduce koa by planting have largely failed, this method of inducing natural regeneration shows enough promise to warrant investigation. If we can reproduce koa naturally over fairly wide areas simply by bulldozing the jungle, reforestation costs will be reduced greatly.

Converting Wildland Forests

Reforestation in Hawaii is centered on the relatively idle acreage of State Forest Reserves. Here a rich timber resource can be developed without damaging the all-important watershed and without displacing other uses. Reforestation can quite possibly cause Hawaii's Forest Reserves to become much more valuable for public recreation than they are now. Some exotic timber species are far more suitable and compatible to recreation use than is the present jungle type. Furthermore, the reserves will be much more accessible to recreationists because of the road system that will be built to carry on the reforestation. It is also possible that planted forests may tolerate controlled grazing by domestic livestock, and may provide a better habitat for upland birds and game animals than do the native forests. If these things happen, in connection with the State's reforestation program, Hawaii will be immensely richer in natural resources.

Reforestation and conversion of wildland forests is beginning in a small way on the relatively idle public- and privately-owned forest land outside of the reserves. On these lands, however, other uses generally hold precedence over commercial timber production, largely because those who administer the lands have had no experience with forest management. It is believed that interest in timber growing on "outside" lands will mount as the timber harvest from the Forest Reserves gets underway and the value of the forest products becomes widely known. Eventually, it is hoped that most of these potential timberlands outside the Forest Reserves, totaling about 600,000 acres, will be put into commercial timber production.

Converting relatively idle wildland forests into productive timberlands is the most important forestry job in Hawaii today. But cultivated agriculture and pasture management also hold forestry opportunities. Erosion poses a problem on much of the cropland in Hawaii because of the excessive slopes that are being farmed. For example, farmers grow sugar cane on slopes as steep as 70 percent. An inventory of soil and water conservation needs for Hawaii prepared by the Soil Conservation Service (Hawaii Conservation Needs Committee 1961) shows that more than two-thirds of the 329,000 acres expected to be in crops in 1975 have a dominant soil erosion problem. The Soil Conservation Service believes it is necessary and feasible to treat erosion on 150,000 acres of this eroding cropland. The inventory also shows that extremely serious erosion plagues 10 percent of the 742,000 acres of range land expected to be grazed in 1975. The most visible areas of soil erosion damage in Hawaii lie on its range lands. In the heavy storms that frequent the islands, silt from eroding range areas and the excessively steep croplands sweeps into the ocean, often discoloring the sea for several miles offshore.

Hawaii's soil resource is not inexhaustible. In fact, the soil mantle is relatively thin on these volcanic islands. Planting commercially important timber trees on some of the rapidly eroding slopes now in crop or pasture use may be a solution of the problem. Tree cover acts as an effective erosion control, and a cash income may be realized when the trees reach marketable size.

This cash income from farm woodlot forestry in Hawaii can be an important item in ranch management. A 36-year-old stand of silk-oak was recently cut down on a sugar plantation on the island of Hawaii to make room for more sugar cane. The stand had produced 106,000 board feet of high-quality hardwood sawtimber per acre, at the rate of 3,000 board feet per acre per year. With stumpage value set conservatively at $40 per thousand board feet, this stand of valuable hardwood timber had produced $120 worth of sawtimber per acre each year since it was planted. The owner had no out-of-pocket expense except for the initial planting cost and the land taxes. It is obvious that planting trees on problem areas of crop or pasture land in Hawaii will not mean taking the land out of production just to protect it from erosion. We may speculate whether somewhat more than just the critical problem areas on Hawaii's croplands and pastures might not be considered for farm forests.

Another area that offers definite opportunity for farm forestry in Hawaii is the production of monkey-pod (Pithecellobium saman) on low-elevation pastures, especially in the more arid sections of the Islands. Monkey-pod ranks as one of the world's most valuable hardwoods. It is used extensively in Hawaii's important craftwood industry. Well-figured monkey-pod sometimes brings in more than $1,000 per thousand board feet. Ironically, although monkey-pod is ideally suited to growing conditions in the State, most of Hawaii's craftwood industry uses monkey-pod wood that is imported from Fiji. Monkey-pod is an ideal tree to grow on arid pasture land, because moisture from ocean fogs condenses on its low, wide crown and causes what is known as "fog drip." In fact, another common name for monkey-pod is "rain-tree." The grass is always greener under the monkey-pods, and the tree reproduces better and thrives better under grazing than it does in ungrazed areas. It would seem that stockmen of Hawaii could profit in several ways by growing this valuable tree in their pastures.

The future for forestry in Hawaii is full of promise. If the million acres suitable for planting are planted with the right timber species, using correct planting methods, and if proper management is applied to the established stands, the State's natural resources will be increased enormously. Also, if some of the problem cropland and pasture areas produce rapid-growing, high-quality hardwood timber, conservation needs can be met--probably at a profit to the landowners. The gains from making full use of the multiple resources of Hawaii's forested area cannot help but bring better social and economic conditions to the State and to the Nation. The forestry program is away to a good start in Hawaii. Farsighted leadership, teamed with adequate research, will insure that Hawaii's forestry continues to progress steadily and in the right direction.

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1962. Opportunities for timber production in Hawaii.
Pacific Southwest Forest and Range Expt. Sta.
Misc. Paper 67. 11 pp., illus.

Hawaii imports 99 percent of its forest products. Yet one-fourth of its land is suited to commercial timber production. Relatively small forest acreage and remoteness from world markets emphasize the need to grow high-quality hardwoods, including the native *Acacia koa*. Studies indicate: (1) sawtimber is being produced at an annual rate of about 30 million board feet; (2) over 200 million board feet can be produced annually when the 400,000 acres of Forest Reserves suited to commercial timber production are fully developed.

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MISCELLANEOUS PAPER

No. 68 1962

PSW FOREST AND RANGE
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AUG 4 1971
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What's happening at San Dimas?

By
R. P. Crouse and L. W. Hill

Fire swept the 17,000-acre San Dimas Experimental Forest in southern California July 20, 1960. Immediately after the fire, the Forest Service, California's Division of Forestry and Department of Water Resources, and Los Angeles County's Fire Department and Flood Control District joined forces in an emergency research program. This program is testing "first aid" treatments aimed at reducing the flood and erosion damage that usually follows fire in southern California's steep, unstable, chaparral-covered mountains. Tests included large contour terraces, grass seeding, channel check dams, and contour row plantings of barley. The long-term water yield studies were begun anew. Now, 18 months and several storms after the fire, here's how things look.

COVER REESTABLISHMENT

To date, the perennial and annual grasses aerially sown in the small watersheds have had no noticeable effect on watershed performance. Because of the weather pattern, the first sowing, in the fall of 1960, resulted in less than 5 percent ground cover. Rains were deficient and poorly distributed that winter. The second sowing, in 1961, did not produce grass seedlings until after the February 1962 rains. By March, after nearly 26 inches of rain, the annual grass began to take off. The perennials had not yet responded.

Only in 875-acre Monroe Canyon is there a substantial annual grass cover. This canyon was the first area seeded in the 1960 fall season and benefited by early fall rains. The second-year crop is now well established. On north-facing deep soils, there is a lush stand 12 to 18 inches high. South-facing deep soils have a good, but less dense cover. Shallow soils, which occupy 700 acres, have a thinner cover augmented by native herbaceous and brush vegetation.

LARGE WATERSHED PERFORMANCE

Fire's aftermath was dramatically demonstrated in Monroe Canyon and adjoining 740-acre Volfe Canyon. Here is the record for two comparable storms--one before the fire, in 1954, and the other after the fire, in 1961:

STORM DATE	Feb. 13, 1954	Dec. 1, 1961
RAINFALL		
Season total before storm	17.0 in.	6.3 in.
Storm total before peak intensity	3.6 in.	2.6 in.
Maximum intensity during storm		
20-minute	0.9 in.	1.2 in.
60-minute	0.7 in.	0.7 in.
FLOOD PEAK FLOW		
Monroe Canyon	4.4 c.f.s.	880 c.f.s.[1]
Volfe Canyon	0.8 c.f.s.	660 c.f.s.[1]

---

[1] Gaging station overwhelmed; estimated from observations made during storm.

Peak flows from the burned watersheds were about 200 to 800 times greater than from the similar storm before the fire. The contrast in debris production was as great. During the 1954 storm, streamflow was regulated, clear, and prolonged. In 1961, most of the flow came in a few minutes and was heavily laden with silt, sand, and boulders. The Monroe streamgaging station was pounded and overwhelmed; after the storm it looked as though it had been hit by an avalanche.

Monroe Canyon, from which 40 acres of riparian growth had been removed 18 months before the fire, showed more evidence of large rock and boulder movement than Volfe. One boulder measuring 7 feet by 4 feet moved more than 300 feet. The channel in Monroe is now loaded with large rock and rubble. The material in Volfe is smaller. It may be that the riparian growth in Volfe screened out the larger material and reduced the flood flow's carrying power.

The gaging flumes in both watersheds are now buried in debris 6 to 8 feet deep. This channel filling extends for a mile above each station on a steady 8 to 9 percent grade.

COMPARISON OF FIRST AID TREATMENTS IN SMALL WATERSHEDS

Grass Sowing

Sown grasses, both annual and perennial, have not yet affected watershed performance. These are results following a year of severe drought. General conclusions concerning the effects of this emergency treatment on watershed performance cannot be drawn from this limited experience. Now, after the February 1962 rainfall, the annual grasses are beginning to grow. We expect them to moderate subsequent storm flow.

Contour Barley Plantings

Row plantings of barley on close contours have so far been very effective. Germination was excellent despite cold weather and low rainfall the winter of 1960-61. The stand was 2 inches high in less than two weeks and formed a substantial barrier to overland flow and sediment transport. Its rapid growth continued, and by spring barley-stalk contour "fences" were firmly established. A good seed crop produced an excellent volunteer stand the winter of 1961-62. The old stalks, plus the new crop, continue to protect against raindrop impact, soil detachment, and overland flow. Thus far the barley planted watersheds have produced the least sediment transport during prolonged storms and during high intensity periods.

Terraces

Terrace performance is less promising, though at first it looked good. Terraced watersheds produced almost no sediment and little streamflow during the small storms of 1960-61 and the first storm of the next rainy season. In subsequent storms, however, failures have occurred in every terraced watershed except those in which barley was also planted. During the second storm of 1961-62, failures occurred when moderately high intensity rainfall exceeded the infiltration and storage capacity of the terraces. In subsequent storms, additional failures occurred immediately after the peak rainfall intensities.

Individual terrace basins failed when the outside berm softened and settled below the level of the drainage system. Once the berms overtopped, large gullies were cut within a few minutes, draining the broken basins and those adjacent. Frequently this large load of water was dumped into the next terrace below, causing a chain raction of failures. This in turn produced relatively high and flashy peak flows with heavy sediment discharges from the terraced watersheds.

Channel Check Dams

Channel checks built of soil cement were designed to stabilize the channel and reduce further undercutting of side slopes. Until these small dams filled, during the second 1961-62 storm, flows from the channel-check watersheds were low and carried very little suspended sediment. After the check dams filled, storm flows were relatively high and heavily laden with sediment, sand, and small gravel. However, there has been less rock and boulder movement than in watersheds without checks.

Observed differences in treatment response have been associated with the intensity of rainfall rather than with the total size of the storm. Most sediment transport and debris movement has occurred within minutes after bursts of high intensity rainfall. When intensities exceeded 1/2-inch per hour, large peak flows and debris loads usually followed.

SUMMARY

1. Eighteen months after the fire, and 15 months after the first seeding, sown grass is still not effective in improving watershed performance. Drought conditions during the first growing season were not favorable for grass growth. It is apparent that because of the great variation in the weather pattern in southern California, generalizations on the results of emergency revegetation cannot be drawn from a single year's experience.

After two months of heavy rain in 1962, however, the annual grasses are finally beginning to take off. We expect them to moderate storm flow in coming months.

2. The burned watersheds can take large quantities of rain in terms of total volume. Rainfall intensity is the real "killer." High peak flows and heavy sediment and debris loads are associated with intensities greater than 1/2-inch per hour.

3. At this writing, barley contour-row plantings (alone and in combination with terraces) seem to be our best first-aid treatment. Terraces, when unaided by barley plantings, have failed and at this time do not appear promising in conditions of steep topography, unstable soils and high intensity storms found in the San Gabriel Mountains.

At San Dimas Experimental Forest the first sizable winter storms brought out some differences in emergency measures being studied as possible first aid for burned watersheds . . .

. . . Barley planted on contour (above) has done a good job of reducing soil movement.

. . . Inexpensive check dams (bottom left) withstood overtopping flows and reduced downcutting of channels.

. . . Large terraces on contour were overtopped and washed out (bottom right) except where slopes were protected by barley plantings.

ACKNOWLEDGMENTS

The San Dimas Experimental Forest is maintained by the Forest Service, U.S. Department of Agriculture in cooperation with the California Division of Forestry. Since 1947 this has been a joint research project with the California Division of Forestry, which participates in program planning and provides financial support. Other long-term cooperators are the Los Angeles County Flood Control District, the Los Angeles County Fire Department, and the University of California, which provide staff or other support or use research facilities at the experimental forest.

Special recognition is due these agencies and the California Department of Water Resources for assistance with emergency rehabilitation work after a wildfire in July 1960. Their cooperation made it possible to restore experimental facilities and start emergency research on methods of managing chaparral watersheds for more effective control of fires, floods and erosion, and water yield.

Research policy and program formulation at the San Dimas Experimental Forest are guided by the following Advisory Committee:

Paul Bauman, Sierra Madre

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James F. Davenport, Southern California Edison Company, Los Angeles

Warren A. Hall, Water Resources Center, University of California, Los Angeles

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MISCELLANEOUS PAPER NO. 69
1962

PSW FOREST AND RANGE
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AUG 4 1971
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A provisional Check List of some common native and introduced Forest Plants in Hawaii

L.W. BRYAN and CLYDE M. WALKER

PACIFIC SOUTHWEST
FOREST AND RANGE
EXPERIMENT STATION
BERKELEY, CALIFORNIA

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

FOREWORD

In 1960 the Pacific Southwest Forest and Range Experiment Station wrote the Hawaii Forestry Division:

> Our desire is to employ [common] names in Forest Service publications that are consistent, acceptable in Hawaii, in harmony with naming practices on the mainland, and in the case of wood products, to encourage the adoption of names that will not come into conflict with the names of other woods that have been accepted by the forest products industries on the mainland. It seems evident that some effort will be required to determine the most generally satisfactory names.

This check list is the first step in that effort. It will serve as the guide for Station publications until a more detailed check list can be compiled and published.

The Station wishes to express its gratitude to Bernice Pauahi Bishop Museum for the work of Marie C. Neal in helping the authors of this publication.

KEITH ARNOLD, Director

A Provisional Check List Of Some Common Native And Introduced Forest Plants in Hawaii

Errata

p. 3. For : Albizia moluccana ------------------ Molucca albizzia (sau)
Read: Albizia falcata (moluccana)---------- Molucca albizzia (sau)

A PROVISIONAL CHECK LIST OF SOME COMMON NATIVE AND INTRODUCED FOREST PLANTS IN HAWAII

By

L. W. Bryan and Clyde M. Walker

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Miscellaneous Paper No. 69 1962

U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
BERKELEY, CALIFORNIA

A PROVISIONAL CHECK LIST OF SOME COMMON NATIVE AND INTRODUCED FOREST PLANTS IN HAWAII

By L. W. Bryan[1] and Clyde M. Walker[2]

When mainland foresters began work on an inventory of Hawaii's timber resources, they found a rich and largely unfamiliar forest. Besides native species of tropical or sub-tropical plants, the forests contained many species introduced from tropical and temperate zones around the world. One of the minor problems of survey foresters was the variability in common names used for species of this rich flora.

Many native species had attractive Hawaiian names, but sometimes Hawaiians had given the same name to all native species of a single genus; sometimes each island of the Hawaiian group had a different name for a single species. Some introduced species had become known in the islands by common names used for other genera or species in other forest regions.

Adoption of uniform common names was highly desirable. This paper is an attempt to compile a check list of preferred names. The list contains three parts: (a) trees, (b) shrubs, woody vines, and herbs, and (c) an index of common names. In the first two parts the plants are listed alphabetically by scientific name. The generic name is followed on the same line by the family name. Then follow the specific names with common names at right. Where several similar or closely related species of a genus bear the same common name, the scientific name is replaced by the abbreviation spp. (species, plural). Synonyms often used are inserted in parentheses, and misapplied names also by the words "of authors."

We have been guided by the Forest Service Tree and Range Plant Name Committee, by Little's discussion of common names,[3] and by Marie C. Neal, botanist of the Bernice Pauahi Bishop Museum in Honolulu, who not only checked common and scientific names in an early draft of this list, but also contributed to the compilation of the list. We are especially grateful for her help.

---

[1] Formerly Deputy State Forester, Hawaii Forestry Division.

[2] Publications Officer, Pacific Southwest Forest and Range Experiment Station.

[3] Little, Elbert L., Jr. Check list of native and naturalized trees of the United States. U.S. Dept. Agr. Agr. Handb. 41. 472 pp. (pp. 14-16). 1953.

Any mistakes are our own, and we recognize that this list leaves opportunities for refinement. For example, when one or more Hawaiian names are given to different species, we have somewhat arbitrarily listed one of these as the preferred name and the others in parentheses. Would a different choice be better? Until such questions are settled, we hope this list will prove acceptable as an interim attempt to clarify and standardize local usage.

TREES

Scientific Name	Common Name
Abies (Pinaceae, pine family)	
kawakamii	Formosa fir
Acacia (Leguminosae, legume family)	
auriculaeformis	earpod acacia
baileyana	Bailey acacia
catechu	catechu acacia
confusa	Formosa koa
decurrens	black-wattle acacia
decurrens var. dealbata	silver-wattle acacia
elata	cedar acacia
farnesiana	klu (popinac, wait-a-bit, sweet acacia)
koa	koa
koaia	koaia
latifolia	broadleaf acacia
longifolia	Sydney acacia
melanoxylon	blackwood acacia
saligna	goldwreath acacia
Agathis (Araucariaceae, araucaria family)	
australis	New Zealand kauri (kauri dammarpine)
robusta	Australian kauri (big dammarpine)
vitiensis	Fijian kauri (Fijian dammarpine)
Albizia (Leguminosae, legume family)	
acle	acle albizzia
julibrissin	silktree
lebbekoides	Indonesian albizzia
moluccana	Molucca albizzia (sau)
montana	mountain albizzia
Alectryon (Sapindaceae, soapberry family)	
macrococcus	mahoe
mahoe	Oahu mahoe
Aleurites (Euphorbiaceae, spurge family)	
fordii	tung-oil-tree
moluccana	kukui (candlenut-tree)
trisperma	banucalog (Philippine kukui, soft lumbang)
Alnus (Betulaceae, birch family)	
nepalensis	Nepal alder
rubra	red alder

Scientific Name	Common Name
Alphitonia (Rhamnaceae, buckthorn family)	
ponderosa (excelsa of authors)	o'a (kauila, tree buckthorn)
Amerimnon: See Dalbergia	
Amoora: See Aphanamixis	
Angophora (Myrtaceae, myrtle family)	
lanceolata (costata)	lanceleaf gum-myrtle
subvelutina	broadleaf gum-myrtle
Antidesma (Euphorbiaceae, spurge family)	
platyphyllum	hame (ha'a, mehame)
pulvinatum	ha'a (mehame, hame)
Aphanamixis (Amoora)(Meliaceae, mahogany family)	
grandifolia	amoora
Araucaria (Araucariaceae, araucaria family)	
angustifolia (brasiliana)	parana-pine (parana araucaria)
bidwillii	bunya-bunya
columnaris (cookii)	columnar araucaria (Cooks araucaria)
cunninghamii	hoop-pine
excelsa	Norfolk-Island-pine
klinkii	Klink araucaria
Archontophoenix (Palmae, palm family)	
alexandrae	Alexandra kingpalm
Artocarpus (Moraceae, mulberry family)	
altilis (incisus)	'ulu (breadfruit)
Bambusa (Gramineae, grass family)	
spp. (and other bamboo genera)	'ohe (bamboo)
Bleekeria (Ochrosia) (Apocynaceae, dogbane family)	
sandwicensis	holei
Bobea (Rubiaceae, madder family)	
spp.	'ahakea
Broussaisia (Saxifragaceae, saxifrage family)	
arguta	kanawao (pu'aha-nui, kanawau)

Scientific Name	Common Name
Callistemon (Myrtaceae, myrtle family)	
salignus	willow bottlebrush
Callitris (Pinaceae, pine family)	
calcarata	black cypress-pine
cupressiformis	drooping cypress-pine
glauca (hugelii)	blue cypress-pine, in Hawaii "white cypress-pine"
macleayana	brush cypress-pine
muelleri	Mueller cypress-pine
Calodendrum (Rutaceae, rue family)	
capense	cape-chestnut
Calophyllum (Guttiferae (Clusiaceae), mangosteen family)	
inophyllum	kamani (kamanu)
Canarium (Burseraceae, bursera family)	
luzonicum	pili-nut-tree
Canthium (Plectronia) (Rubiaceae, madder family)	
odoratum	alahe'e (walahe'e)
Cassia (Leguminosae, legume family)	
gaudichaudii	kolomona
glauca	glossy-shower senna (kolomona, kalamona)
laevigata	smooth senna (kolomona, kalamona)
leschenaultiana	lauki
Castanospermum (Leguminosae, legume family)	
australe	Moreton-Bay-chestnut (blackwood)
Casuarina (Casuarinaceae, casuarina family)	
cunninghamiana	river-oak casuarina, in Hawaii "ironwood"
equisetifolia	horsetail casuarina, in Hawaii "shortleaf ironwood"
glauca	longleaf casuarina, in Hawaii "longleaf ironwood"
montana	mountain casuarina, in Hawaii "mountain ironwood"
papuana	Papuan casuarina, in Hawaii "Papuan ironwood"

Scientific Name	Common Name
Casuarina (con.)	
stricta (quadrivalvis)	coast casuarina, in Hawaii "coast ironwood"
suberosa	black-she-oak casuarina
torulosa	corkbark casuarina, in Hawaii "corkbark ironwood"
Catalpa (Bignoniaceae, bignonia family)	
longissima	Haiti catalpa (yokewood)
Cecropia (Moraceae, mulberry family)	
sp.	trumpet-tree
Cedrela (Meliaceae, mahogany family)	
odorata	Spanish-cedar (Central-American-cedar, cigarbox cedrela)
Cedrus (Pinaceae, pine family)	
deodara	deodar cedar
Ceodes: See Pisonia	
Chamaecyparis (Pinaceae, pine family)	
lawsoniana	Port-Orford-cedar
obtusa	hinoki false-cypress
pisifera	benihi (sawara false-cypress)
Charpentiera (Amaranthaceae, amaranth family)	
obovata	papala
Cheirodendron (Araliaceae, ginseng family)	
gaudichaudii	'olapa (kauila-mahu, lapalapa)
platyphyllum	lapalapa (kauila-mahu, 'olapa)
Chenopodium (Chenopodiaceae, goosefoot family)	
oahuense (sandwiceum)	'aheahea (alaweo)
Chrysophyllum: See Nesoluma	
Cibotium (Cyatheaceae, treefern family)	
chamissoi	hapu'u (Hawaiian treefern)
glaucum	hapu'u (Hawaiian treefern)
menziesii	hapu'u-'i'i (Hawaiian treefern)
Cinchona (Rubiaceae, madder family)	
pubescens (succirubra)	redbark cinchona (quinine-tree)

Scientific Name	Common Name
Cinnamomum (Lauraceae, laurel family)	
camphora	camphor-tree
zeylanicum	cinnamon (Ceylon cinnamon)
Claoxylon (Euphorbiaceae, spurge family)	
sandwicense	po'ola
Colubrina (Rhamnaceae, buckthorn family)	
oppositifolia	kauila
Coprosma (Rubiaceae, madder family)	
spp.	pilo
Cordia (Boraginaceae, borage family)	
subcordata	kou
Corynocarpus (Corynocarpaceae, karaka family)	
laevigata	karaka (New Zealand karakanut)
Cryptocarya (Lauraceae, laurel family)	
mannii	holio
Cryptomeria (Pinaceae, pine family)	
japonica	sugi (Japanese cryptomeria)
Cunninghamia (Pinaceae, pine family)	
lanceolata	China-fir
Cupressus (Pinaceae, pine family)	
arizonica	Arizona cypress
lusitanica	Mexican cypress
macrocarpa	Monterey cypress
sempervirens	Italian cypress
Dalbergia (Amerimnon) (Leguminosae, legume family)	
cuscatlantica	funera
sissoo	sissoo
Diospyros (Maba)(Ebenaceae, ebony family)	
ferrea (sandwicensis)	lama
Dodonaea (Sapindaceae, soapberry family)	
viscosa	'a'ali'i ('a'ali'i-kumakua)
Dracaena (Pleomele)(Liliaceae, lily family)	
aurea	hala-pepe

Scientific Name	Common Name
Dubautia (Railliardia)(Compositae, composite family)	
arborea	na'ena'e (kohola-pehu)
Elaeocarpus (Elaeocarpaceae, elaeocarpus family)	
bifidus	kalia
grandis	blue marble-tree
serratus	Ceylon-olive
Entandrophragma (Meliaceae, mahogany family)	
delvoyi	sapele (African-mahogany)
Enterolobium (Leguminosae, legume family)	
cyclocarpum	earpod-tree (guanacaste)
Erythrina (Leguminosae, legume family)	
sandwicensis (monosperma of authors)	wiliwili
Eucalyptus (Myrtaceae, myrtle family)	
alba	ghost-tree eucalyptus
astringens	brown-mallet eucalyptus
baileyana	rough stringybark eucalyptus
baueriana	bluebox eucalyptus
beyeri	Beyer ironbark eucalyptus
bosistoana	coast graybox eucalyptus
botryoides	bangalay eucalyptus
calophylla	Port Gregory eucalyptus (marri)
camaldulensis (rostrata)	river redgum eucalyptus
campanulata	stringybark peppermint eucalyptus
camphora	camphor eucalyptus
citriodora	lemon eucalyptus
cladocalyx	sugar-gum eucalyptus
cloeziana	gympie messmate eucalyptus
coccifera	peppermint-gum eucalyptus
consideniana	yertchuk eucalyptus
cornuta	yate eucalyptus
crebra (racemosa)	narrowleaf ironbark eucalyptus
dalrympleana	mountain-gum eucalyptus
deanei	Deane eucalyptus
deglupta	Amammanit eucalyptus
delegatensis (gigantea)	alpine-ash eucalyptus
diversicolor	karri eucalyptus
dives	blue peppermint eucalyptus
erythronema	Mt. Lindsay eucalyptus
eximia	yellow bloodwood eucalyptus

Scientific Name	Common Name
Eucalyptus (con.)	
exserta	Queensland redgum eucalyptus
fastigata	brown-barrel eucalyptus
fraxinoides	white-ash eucalyptus
globulus	bluegum eucalyptus
gomphocephala	tuart eucalyptus
goniocalyx	mountain graygum eucalyptus
grandis	rosegum eucalyptus
guilfoylei	yellow tingle eucalyptus
gummifera (corymbosa)	bloodwood eucalyptus
largiflorens (bicolor)	blackbox eucalyptus
longifolia	longleaf woolybutt eucalyptus
macrorrhyncha	red stringybark eucalyptus
maculata	spotted-gum eucalyptus
maidenii	Maiden-gum eucalyptus
marginata	jarrah eucalyptus
melliodora	yellowbox eucalyptus
microcorys	tallowwood eucalyptus
nitens	shining eucalyptus
obliqua	messmate stringybark eucalyptus
paniculata	gray ironbark eucalyptus
pauciflora	snowgum eucalyptus
pellita	slatyhide eucalyptus
pilularis	blackbutt eucalyptus
polyanthemos	redbox eucalyptus
populnea (populifolia)	poplarleaf eucalyptus
propinqua	graygum eucalyptus
pulverulenta	silverleaf eucalyptus
punctata	leather-jacket eucalyptus
radiata	peppermint eucalyptus
regnans	mountain-ash eucalyptus
resinifera	kinogum eucalyptus (redmahogany eucalyptus)
robertsonii	narrow-leaf peppermint eucalyptus
robusta	robusta eucalyptus (swamp-mahogany eucalyptus)
rubida	candlebark eucalyptus
rudis	desert eucalyptus
saligna	saligna eucalyptus (floodedgum eucalyptus)
salmonophloia	salmon eucalyptus
salubris	gimlet eucalyptus
scabra (eugenioides)	white stringybark eucalyptus
siderophloia	broadleaf ironbark eucalyptus
sideroxylon	red-ironbark eucalyptus
sieberiana	silvertop eucalyptus
stellulata	olive-green eucalyptus
stuartiana (bridgesiana)	apple-box eucalyptus
tereticornis (umbellata)	forest redgum eucalyptus

Scientific Name	Common Name
Eucalyptus (con.)	
tessellaris	Moreton-Bay eucalyptus
tetraptera	fourwing eucalyptus
torelliana	cadagi eucalyptus
torquata	flower coral eucalyptus
triantha (acmenioides)	triantha eucalyptus
viminalis	manna eucalyptus
Eugenia (Syzygium, Jambosa) (Myrtaceae, myrtle family)	
cumini	Java-plum (jambolan)
jambos	roseapple ('ohi'a-loke)
malaccensis	'ohi'a-'ai (mountain-apple, Malay-apple
sandwicensis	'ohi'a-ha (pa'ihi)
Euphorbia (Euphorbiaceae, spurge family)	
lorifolia	'akoko (koko)
Eupritchardia: See Pritchardia	
Eurya (Theaceae, tea family)	
sandwicensis	anini (wanini)
Fagara: See Zanthoxylum	
Ficus (Moraceae, mulberry family)	
benjamina	Benjamin fig
elastica	India-rubber fig
macrophylla	Moreton-Bay fig
microcarpa (retusa of authors)	Chinese banyan
nota	rough-leaf fig
parcelii	mosaic fig
religiosa	botree fig (peepul-tree)
rubiginosa	Port Jackson fig
sycomorus	mulberry fig
Filicium (Sapindaceae, soapberry family)	
decipiens	ferntree
Flindersia (Rutaceae, rue family)	
australis	Crows-ash
brayleyana	Queensland-maple (silkwood)
ifflaiana	Cairns-hickory
Fraxinus (Oleaceae, olive family)	
uhdei	tropical ash (Shamel ash, Hawaiian ash)
Gardenia (Rubiaceae, madder family)	
brighamii	na'u (nanu)

Scientific Name	Common Name
Gardenia (con.)	
remyi	nanu (na'u)
Gleditsia (Leguminosae, legume family)	
triacanthos	honeylocust
Gouldia (Rubiaceae, madder family)	
spp.	manono
Grevillea (Proteaceae, protea family)	
robusta	silk-oak
Heliocarpus (Tiliaceae, linden family)	
americanus	heliocarpus (white moho)
Hibiscadelphus (Malvaceae, mallow family)	
hualalaiensis	hau-kuahiwi
Hibiscus (Malvaceae, mallow family)	
elatus	Cuban bast (mahoe, Jamaica linden hibiscus)
tiliaceus	hau (sea hibiscus)
Hymenaea (Leguminosae, legume family)	
courbaril	courbaril (West-Indian-locust)
Ilex (Aquifoliaceae, holly family)	
anomala (sandwicensis)	kawa'u ('aiea)
Jacaranda (Bignoniaceae, bignonia family)	
mimosifolia (ovalifolia)	jacaranda
Juglans (Juglandaceae, walnut family)	
nigra	black walnut
Juniperus (Pinaceae, pine family)	
bermudiana	Bermuda juniper
californica	California juniper
chinensis	Chinese juniper
lucayana (australis)	West Indies juniper
sabina	savin
scopulorum	Rocky Mountain juniper
virginiana	eastern redcedar
Khaya (Meliaceae, mahogany family)	
nyasica	Nyassa khaya
senegalensis	Senegal khaya
Kokia (Malvaceae, mallow family)	
spp.	koki'o

Scientific Name	Common Name
Labordia (Loganiaceae, logania family)	
spp.	kamakahala
Lagerstroemia (Lythraceae, loosestrife family)	
speciosa	queen crapemyrtle, in Hawaii "queen flower"
Lagunaria (Malvaceae, mallow family)	
patersonii	Paterson sugarplumtree (whitewood)
Leptospermum (Myrtaceae, myrtle family)	
laevigatum	coast teatree (Victoria teatree)
scoparium	manuka (broom teatree)
Leucaena (Leguminosae, legume family)	
glauca (leucocephala)	koa-haole (e-koa, leadtree)
Libocedrus (Pinaceae, pine family)	
decurrens	incense-cedar
Maba: See Diospyros	
Macaranga (Euphorbiaceae, spurge family)	
grandifolia	macaranga (bing-a-bing)
Mangifera (Anacardiaceae, cashew family)	
indica	mango (manako)
Manihot (Euphorbiaceae, spurge family)	
glaziovii	Ceara rubber-tree
Melaleuca (Myrtaceae, myrtle family)	
armillaris	bracelet-tea-tree
leucadendron	cajeput-tree (paper-bark)
Melia (Meliaceae, mahogany family)	
azedarach	chinaberry (pride-of-India)
Melochia (Sterculiaceae, sterculia (cocoa) family)	
indica	melochia
Metrosideros (Myrtaceae, myrtle family)	
collina (polymorpha)	'ohi'a-lehua
Mezoneuron (Leguminosae, legume family)	
kauaiense	uhiuhi

Scientific Name	Common Name
Morinda (Rubiaceae, madder family)	
citrifolia	noni (Indian-mulberry)
Myoporum (Myoporaceae, myoporum family)	
sandwicense	naio (aaka, false sandalwood)
Myrica (Myricaceae, waxmyrtle family)	
cerifera	southern bayberry, in Hawaii "wax-myrtle"
faya	firetree
Myroxylon (Leguminosae, legume family)	
balsamum (toluiferum)	tolu-balsam (balmtree)
Myrsine (Suttonia)(Myrsinaceae, myrsine family)	
spp.	kolea
Nesoluma (Chrysophyllum)(Sapotaceae, sapote (sapodilla) family)	
polynesicum	keahi
Nothocestrum (Solanaceae, nightshade family)	
spp.	'aiea
Nototrichium (Amaranthaceae, amaranth family)	
sandwicense	kulu'i
Ochroma (Bombacaceae, bombax family)	
pyramidale (lagopus)	balsa
Ochrosia: See Bleekeria	
Olea (Oleaceae, olive family)	
europaea	olive
Osmanthus (Oleaceae, olive family)	
sandwicensis	olopua (pua)
Osteomeles (Rosaceae, rose family)	
anthyllidifolia	'ulei (Polynesian bonyberry)
Pandanus (Pandanaceae, screwpine family)	
tectorius	hala (puhala, screwpine)
Parkia (Leguminosae, legume family)	
timoriana	cupang (nitta-tree)

Scientific Name	Common Name
Pelea (Rutaceae, rue family)	
spp.	alani
Peltophorum (Baryxylum)(Leguminosae, legume family)	
africanum	African peltophorum
inerme (roxburghii)	yellow-poinciana
Perrottetia (Celastraceae, bittersweet family)	
sandwicensis	olomea (wai-mea)
Picea (Pinaceae, pine family)	
abies	Norway spruce
engelmannii	Engelmann spruce
pungens	blue spruce
sitchensis	Sitka spruce
Pinus (Pinaceae, pine family)	
armandii	Armand pine
attenuata X radiata	knobcone-Monterey hybrid pine
ayacahuite	Mexican white pine
bungeana	lacebark pine
canariensis	Canary-Island pine
contorta	lodgepole pine
densiflora	Japanese red pine
echinata	shortleaf pine
elliottii	slash pine
glabra	spruce pine
insularis	Philippine pine
lambertiana	sugar pine
montezumae var. rudis	Montezuma pine
monticola	western white pine
nigra (laricio)	Austrian pine
occidentalis	Cuba pine
palustris	longleaf pine
patula	jelecote pine
peuce	Balkan pine
pinaster	cluster pine
pinea	Italian stone pine
ponderosa	ponderosa pine
pungens	table-mountain pine
radiata	Monterey pine
resinosa	red pine
rigida	pitch pine
roxburghii (longifolia)	chir pine
serotina	pond pine
strobus	eastern white pine
sylvestris	Scotch pine

Scientific Name	Common Name
Pinus (con.)	
taeda	loblolly pine
thunbergii	Japanese black pine
torreyana	Torrey pine
yunnanensis	Yunnan pine
Pipturus (Urticaceae, nettle family)	
albidus	mamaki
Pisonia (Ceodes, Rockia)(Nyctaginaceae, four-o'clock family)	
spp.	papala-kepau
Pithecellobium (Leguminosae, legume family)	
dulce	opiuma
saman (Samanea saman)	monkey-pod (raintree)
Pittosporum (Pittosporaceae, pittosporum family)	
spp. (all Hawaiian species)	ho'awa
undulatum	orangeberry pittosporum
Planchonella: See Pouteria	
Platanus (Platanaceae, sycamore (planetree) family)	
occidentalis	American sycamore
Platydesma (Rutaceae, rue family)	
campanulatum	pilo-kea
Platymiscium (Leguminosae, legume family)	
stipulare	roble
Plectronia: See Canthium	
Pleomele: See Dracaena	
Podocarpus (Taxaceae, yew family)	
gracilior	musengera podocarpus
javanicus (cupressina)	Java podocarpus
Pouteria (Planchonella, Sideroxylon) (Sapotaceae, sapote (sapodilla) family)	
sandwicensis	'ala'a (aulu)
Pritchardia (Eupritchardia)(Palmae, palm family)	
spp.	loulu

Scientific Name	Common Name
Prosopis (Leguminosae, legume family)	
pallida	kiawe (mesquite)
Pseudotsuga (Pinaceae, pine family)	
menziesii (taxifolia)	Douglas-fir
Psidium (Myrtaceae, myrtle family)	
cattleianum (littorale)	strawberry guava (waiwai-'ula'ula)
guajava	guava
Pteralyxia (Apocynaceae, dogbane family)	
macrocarpa	kaulu
Pterocarpus (Leguminosae, legume family)	
echinatus	prickly narra
indicus	narra (Burmacoast padauk)
marsupium	bibla (Vengai padauk)
Pterotropia: See Tetraplasandra	
Quercus (Fagaceae, beech family)	
suber	cork oak
Railliardia: See Dubautia	
Rauvolfia (Apocynaceae, dogbane family)	
sandwicensis	hao
Reynoldsia (Araliaceae, ginseng family)	
sandwicensis	'ohe-makai ('ohe-kukaluae'o)
Rhus (Anacardiaceae, cashew family)	
javanica (chinensis, semialata)	neneleau (neleau)
Ricinus (Euphorbiaceae, spurge family)	
communis	castor-bean (koli, pa'aila)
Rockia: See Pisonia	
Sadleria (Polypodiaceae, fern family)	
spp.	'ama'uma'u ('ama'u, ma'uma'u)
Samanea: See Pithecellobium	
Santalum (Santalaceae, sandalwood family)	
spp. (all Hawaiian species)	'ili-ahi (sandalwood)
album	white sandalwood

Scientific Name	Common Name
Sapindus (Sapindaceae, soapberry family)	
saponaria	wingleaf soapberry (manele, a'e)
oahuensis	lonomea (aulu, kaulu)
Schinus (Anacardiaceae, cashew family)	
terebinthifolius	Christmas-berry
Schizolobium (Leguminosae, legume family)	
parahybum (excelsum)	guapuruvu (amber, zorra)
Sequoia (Pinaceae, pine family)	
sempervirens	redwood
Sesbania (Leguminosae, legume family)	
tomentosa	'ohai
Sophora (Edwardsia)(Leguminosae, legume family)	
chrysophylla	mamane
Spathodea (Bignoniaceae, bignonia family)	
campanulata	African tuliptree
Straussia (Rubiaceae, madder family)	
spp.	kopiko ('opiko)
Styphelia (Epacridaceae, epacris family)	
tameiameiae	pukiawe
Suttonia: See Myrsine	
Swietenia (Meliaceae, mahogany family)	
macrophylla	Honduras mahogany
mahagoni	West Indies mahogany
Syncarpia (Myrtaceae, myrtle family)	
glomulifera (laurifolia)	turpentine-tree (turpentine-myrtle)
Taxodium (Pinaceae, pine family)	
distichum	baldcypress
mucronatum	Montezuma baldcypress
Tectona (Verbenaceae, verbena family)	
grandis	teak
Terminalia (Combretaceae, combretum family)	
myriocarpa	jhalna
Tetraplasandra (Pterotropia)(Araliaceae, ginseng family)	
spp.	'ohe'ohe

Scientific Name	Common Name
Thespesia (Malvaceae, mallow family)	
populnea	milo (portiatree)
Thuja (Pinaceae, pine family)	
occidentalis	northern white-cedar
plicata	western redcedar
Toona (Meliaceae, mahogany family)	
ciliata var. australis	Australian toon (Australian redcedar)
Touchardia (Urticaceae, nettle family)	
latifolia	olona
Trema (Ulmaceae, elm family)	
orientalis	gunpowder-tree (charcoal-tree)
Triplaris (Polygonaceae, buckwheat family)	
americana	vara-santa (longjohn anttree)
Tristania (Myrtaceae, myrtle family)	
conferta	brushbox
Ulmus (Ulmaceae, elm family)	
americana	American elm
parvifolia	Chinese elm
Urera (Urticaceae, nettle family)	
sandwicensis	opuhe
Vitex (Verbenaceae, verbena family)	
parviflora	Philippine vitex
Wikstroemia (Thymelaeaceae, mezereum family)	
spp.	'akia
Xylosma (Flacourtiaceae, flacourtia family)	
spp.	maua (xylosma)
Zanthoxylum (Fagara)(Rutaceae, rue family)	
spp.	a'e (kawa'u)

SHRUBS, WOODY VINES, AND HERBS

Scientific Name	Common Name
Abutilon (Malvaceae, mallow family)	
incanum	ma'o (hoary abutilon, Indian-mallow abutilon)
Alocasia (Araceae, arum family)	
macrorrhiza	'ape (giant alocasia)
Alyxia (Apocynaceae, dogbane family)	
olivaeformis	maile (maile alyxia)
Ardisia (Myrsinaceae, myrsine family)	
crispa (crenulata)	Hilo-holly
solanacea (humilis of authors)	shoebutton ardisia
Argyroxiphium (Compositae, composite family)	
sandwicense	'ahinahina (silversword)
Arundina (Orchidaceae, orchid family)	
bambusifolia	bamboo orchid
Asplenium (Polypodiaceae, fern family)	
nidus	'ekaha (birds-nest-fern)
trichomanes	'owali'i
unilaterale	pamoho
Astelia (Liliaceae, lily family)	
spp.	pa'iniu
Bidens (Compositae, composite family)	
spp.	ko'oko'olau (bur-marigold)
Boerhaavia (Nyctaginaceae, four-o'clock family)	
spp.	alena
Botrychium (Ophioglossaceae, adderstongue family)	
subbifoliatum	makou
Buddleia (Loganiaceae, logania family)	
asiatica	huelo-'ilio (Asian butterflybush)
Caesalpinia (Leguminosae, legume family)	
spp.	kakalaioa
Callicarpa (Verbenaceae, verbena family)	
americana	American beauty-berry
Callistemon (Myrtaceae, myrtle family)	
citrinus (lanceolatus)	red bottlebrush

Scientific Name	Common Name
Canavalia (Leguminosae, legume family)	
galeata	'awikiwiki (puakauhi)
Capparis (Capparidaceae, caper family)	
sandwichiana	pua-pilo (maiapilo)
Cassytha (Lauraceae, laurel family)	
filiformis	kauna'oa-pehu (pololo)
Cladium: See Machaerina	
Clermontia (Campanulaceae, bellflower family)	
gaudichaudii	haha
Clidemia (Melastomataceae, melastome family)	
hirta	clidemia
Cocculus (Menispermaceae, moonseed family)	
ferrandianus	huehue
Commelina (Commelinaceae, spiderwort family)	
diffusa	honohono (wandering-jew)
Coprosma (Rubiaceae, madder family)	
ernodeoides	kukae-'ua'u (kukae-nene)
Cordyline (Liliaceae, lily family)	
terminalis	ti (ki, common dracena)
Crotalaria (Leguminosae, legume family)	
spp.	rattlebox
Curcuma (Zingiberaceae, ginger family)	
domestica (longa)	'olena (common turmeric)
Cuscuta (Convolvulaceae, morning-glory family)	
sandwichiana	kauna'oa
Cyanea (Campanulaceae, bellflower family)	
spp.	hahanui
Cyrtandra (Gesneriaceae, gesneria family)	
spp. (all native species)	mapele (ha'i-wale)
begoniaefolia	'ilihia
Cytisus (Leguminosae, legume family)	
scoparius	Scotch broom

Scientific Name	Common Name
Desmondium (Leguminosae, legume family)	
uncinatum (sandwicense)	pua-pilipili (kikania-pipili)
Dianella (Liliaceae, lily family)	
spp.	'uki'uki
Dicranopteris (Gleichenia)(Gleicheniaceae, vinefern family)	
linearis (and other species)	uluhe (false staghorn fern)
Dioscorea (Dioscoreaceae, yam family)	
alata	uhi (edible yam—cultivated for food)
bulbifera (sativa)	hoi (bitter yam)
pentaphylla	pi'a (wild yam)
Dryopteris (Cyclosorus)(Polypodiaceae, fern family)	
cyatheoides	kikawaio (lau-kahi)
Dubautia (Railliardia)(Compositae, composite family)	
spp.	kohola-pehu (na'ena'e, hahanui)
Elaphoglossum (Polypodiaceae, fern family)	
spp.	'ekaha-'ula (mauke)
Emex (Polygonaceae, buckwheat family)	
spinosa	emex
Eupatorium (Compositae, composite family)	
adenophorum (glandulosum of authors)	pa-makani-haole (white thoroughwort)
riparium	Hamakua-pamakani (smaller white thoroughwort)
Exocarpus (Santalaceae, sandalwood family)	
spp.	heau
Fragaria (Rosaceae, rose family)	
chiloensis	'ohelo-papa (native strawberry)
Freycinetia (Pandanaceae, screwpine family)	
arborea (arnottii)	'ie'ie
Geranium (Geraniaceae, geranium family)	
spp.	noho-anu
Gossypium (Malvaceae, mallow family)	
tomentosum	huluhulu (ma'o, Hawaiian cotton)

Scientific Name	Common Name
Gunnera (Haloragaceae, water-milfoil family)	
petaloides (and other species)	'ape'ape
Hedyotis (Kadua)(Rubiaceae, madder family)	
spp.	kio'ele (pilo)
Hibiscus (Malvaceae, mallow family)	
spp. (all species)	aloalo
brackenridgei	ma'o-hau-hele (Hawaiian yellow hibiscus)
kokio	koki'o, (Hawaiian red hibiscus)
Hillebrandia (Begoniaceae, begonia family)	
sandwicensis	aka'aka'awa (pua-maka-nui)
Hydrocotyle (Umbelliferae, carrot family)	
verticillata	pohe (pohepohe, marsh pennywort)
Hymenophyllum (Hymenophyllaceae, filmyfern family)	
lanceolatum	palai-hinahina
obtusum	palai-lau-li'i
Indigofera (Leguminosae, legume family)	
suffruticosa (anil)	'inikoa ('iniko, kolu, anil indigo)
Ipomoea (Convolvulaceae, morning-glory family)	
spp. (all species)	koali (morning-glory)
cairica	koali-'ai
pes-caprae	pohuehue
Isodendrion (Violaceae, violet family)	
spp.	aupaka
Kadua: See Hedyotis	
Korthalsella (Loranthaceae, mistletoe family)	
spp.	hulu-moa (kaumahana, Hawaiian mistletoe)
Lantana (Verbenaceae, verbena family)	
camara	lakana (lantana)
Lipochaeta (Compositae, composite family)	
spp.	nehe

Scientific Name	Common Name
Lobelia (Campanulaceae, bellflower family)	
spp.	'oha-wai ('oha)
gaudichaudii	pu'e
yuccoidea	panaunau
Lycopodium (Lycopodiaceae, clubmoss family)	
cernuum	wawae-'iole (clubmoss)
Machaerina (Cladium, vicentia)(Cyperaceae, sedge family)	
angustifolia	'uki
meyenii	'aha-niu ('uki)
Marattia (Marattiaceae, marattia family)	
douglasii	pala (Hawaii marattia)
Melaleuca (Myrtaceae, myrtle family)	
ericifolia	heath melaleuca (swamp tea-tree)
hypericifolia	dotted melaleuca (tea-tree)
Melastoma (Melastomataceae, melastome family)	
malabathricum	Malabar melastome
Microlepia (Polypodiaceae, fern family)	
setosa	palai (palapalai)
Mirabilis (Nyctaginaceae, four-o'clock family)	
jalapa	nani-ahiahi (four-o'clock)
Mucuna (Leguminosae, legume family)	
gigantea	ka'e'e (ka'e'e'e)
Musa (Musaceae, banana family)	
spp.	mai'a (banana)
Nephrolepis (Polypodiaceae, fern family)	
spp.	okupukupu (kupukupu, ni-ani'au, swordfern)
Neraudia (Urticaceae, nettle family)	
spp.	ma'aloa (ma'oloa, 'oloa)
Nertera (Rubiaceae, madder family)	
granadensis (depressa)	makole (beadplant)
Nicotiana (Solanaceae, nightshade family)	
glauca	tree tobacco (paka)

Scientific Name	Common Name
Nicotiana (con.)	
tabacum	tobacco (paka)
Ophioglossum (Ophioglossaceae, adderstongue family)	
concinnum	pololei (adderstongue)
pendulum	puapua-moa
Passiflora (Passifloraceae, passion-flower family)	
edulis	liliko'i (purple water lemon, purple granadilla)
ligularis	lemi-wai (lemona, sweet granadilla)
Pellaea (Polypodiaceae, fern family)	
ternifolia	kalamoho (kalamoho-lau-li'i)
Peperomia (Piperaceae, pepper family)	
spp.	'ala'ala-wai-nui
Peucedanum (Umbelliferae, carrot family)	
sandwicense	makou
Phajus (Phaius)(Orchidaceae, orchid family)	
tankervilliae (grandifolius)	Chinese ground orchid
Phyllostegia (Labiatae, mint family)	
glabra	ulihi
grandiflora	kapana
racemosa	kiponapona
Physalis (Solanaceae, nightshade family)	
peruviana	poha (cape-gooseberry, Peruvian groundcherry)
Phytolacca (Phytolaccaceae, pokeweed family)	
sandwicensis	popolo-ku-mai (Hawaiian pokeberry)
Piper (Piperaceae, pepper family)	
methysticum	'awa (kava)
Plantago (Plantaginaceae, plantain family)	
major	lau-kahi (broadleaf plantain)
pachyphylla	manene (Kauai plantain)
princeps	ale
Pluchea (Compositae, composite family)	
indica	Indian pluchea (Indian marsh fleabane)

Scientific Name	Common Name
Pluchea (con.)	
odorata	sourbush (hairy fleabane)
Polypodium (Polypodiaceae, fern family)	
hymenophylloides	pai
pellucidum	'ae
saffordii	kihe
spectrum	pe'ahi
Pteridium (Polypodiaceae, fern family)	
aquilinum (Pteris aquilina)	kilau (bracken)
Pteris (Polypodiaceae, fern family)	
spp.	iwa (iwa-puakea, mana, brake)
Railliardia: See Dubautia	
Ranunculus (Ranunculaceae, buttercup family)	
spp.	'awa-Kanaloa (makou)
Rhodomyrtus (Myrtaceae, myrtle family)	
tomentosa	downymyrtle (downy rosemyrtle)
Rubus (Rosaceae, rose family)	
hawaiiensis and R. macraei	'akala ('akalakala)
penetrans	evergreen blackberry
rosaefolius	thimbleberry (ola'a, 'akala, 'akalakala)
Rumex (Polygonaceae, buckwheat family)	
giganteus	pawale (Hawaiian dock)
Scaevola (Goodeniaceae, goodenia family)	
spp.	naupaka (mountain species: naupaka-kuahiwi; beach species: naupaka-kahakai)
Senecio (Compositae, composite family)	
mikanioides	German-ivy (ivy groundsel)
Sida (Malvaceae, mallow family)	
spp.	'ilima
Smilax (Liliaceae, lily family)	
sandwicensis	pi'oi (hoi-kuahiwi)
Solanum (Solanaceae, nightshade family)	
nigrum	popolo (black nightshade)
Spathoglottis (Orchidaceae, orchid family)	
plicata	Malayan ground orchid

Scientific Name	Common Name
Stachytarpheta (Verbenaceae, verbena family)	
jamaicensis	oi (owi, Jamaica false-vervain)
Stenogyne (Labiatae, mint family)	
rotundifolia	pua'a-i-naka
rugosa	ma'ohi'ohi
Strongylodon (Leguminosae, legume family)	
lucidum	nuku-'i'iwi
Trichomanes (Hymenophyllaceae, filmyfern family)	
davallioides	palai-hihi
Tritonia (Iridaceae, iris family)	
crocosmaeflora	crocus tritonia
Ulex (Leguminosae, legume family)	
europaeus	gorse
Vaccinium (Ericaceae, heath family)	
spp.	'ohelo (Hawaiian cranberry)
Verbena (Verbenaceae, verbena family)	
litoralis	ha'uoi (oi, owi)
Viola (Violaceae, violet family)	
spp.	kalili (pohe-hiwa, violet)
Zingiber (Zingiberaceae, ginger family)	
zerumbet	'awapuhi ('opuhi, wild ginger)

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Lists scientific and common names for more than 150 genera of trees plus several shrubs, ferns, and vines.

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Miscellaneous Paper 70
1962

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CALIFORNIA'S 1961 FIRE WEATHER BRINGS NEAR-RECORD LOSSES

Arthur R. Pirsko

PACIFIC SOUTHWEST
FOREST AND RANGE
EXPERIMENT STATION
BERKELEY, CALIFORNIA

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

CALIFORNIA'S 1961 FIRE WEATHER
BRINGS NEAR-RECORD LOSSES

By

Arthur R. Pirsko,
Research Forester

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U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
Berkeley, California

CALIFORNIA'S 1961 FIRE WEATHER
BRINGS NEAR-RECORD LOSSES

By

Arthur R. Pirsko,
Research Forester

Weather conducive to severe fires brought near-record losses from fire damage to California in 1961. Disastrous blazes charred and blackened nearly a thousand homes and other structures located in wildland areas. The State also suffered the largest acreage loss in almost 40 years. Only once before--in 1924--did wildland fire damage in California exceed the 471,000 acres of forest, brush, and grassland burned in 1961.

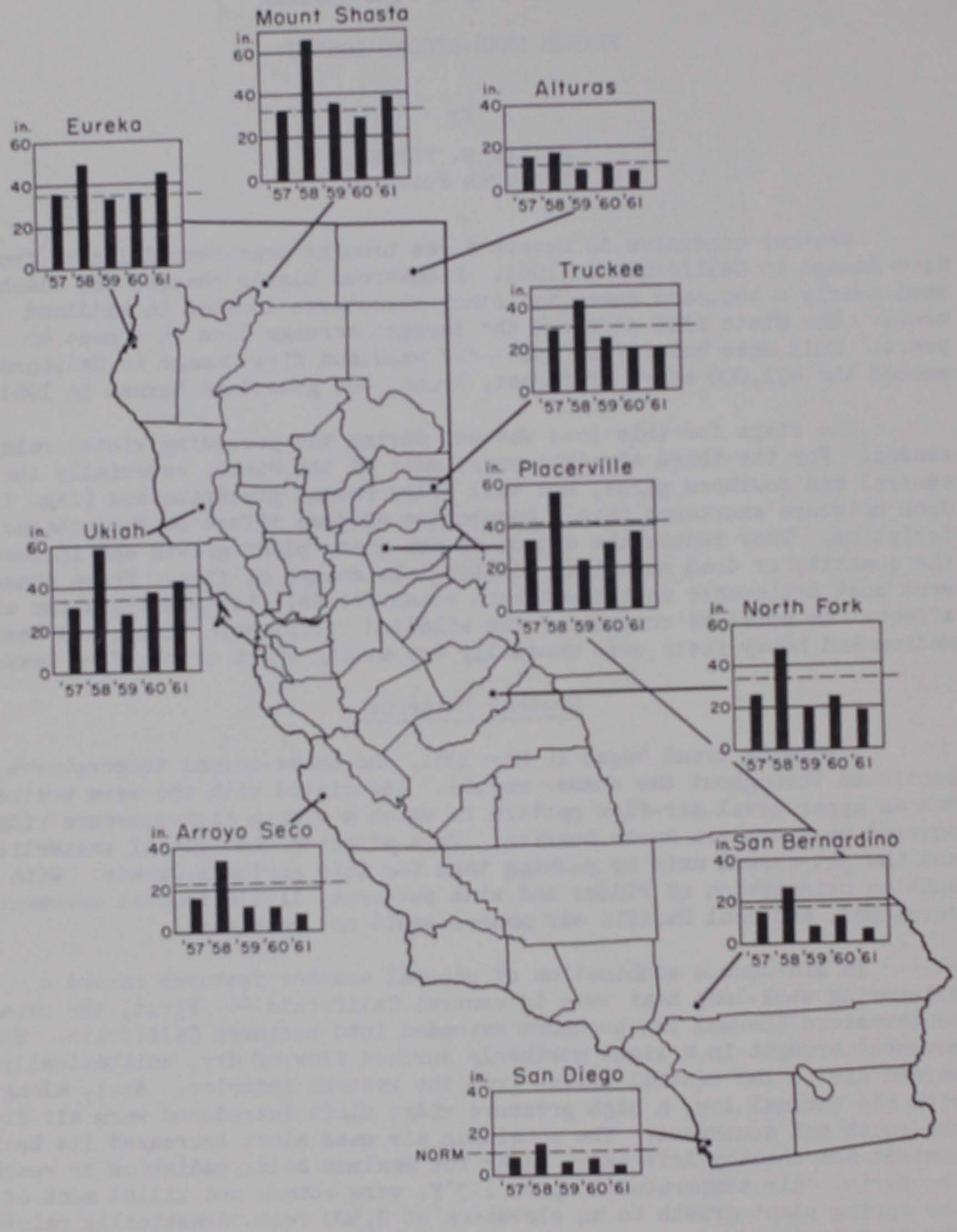
The stage for this loss was set during the preceding winter rainy season. For the third straight year, most of the State, especially the central and southern parts, had well below normal precipitation (fig. 1). Such moisture shortages have a cumulative adverse effect on fuel characteristics. They reduce the amount of new green plant growth and increase the quantity of dead material, boosting the danger of fire. These changes were most noticeable in the southern brush fields. Low precipitation also affects the moisture content of the wildland fuels--both living and dead. Medium and heavy fuels were unusually dry at the start of the fire season.

Weather Patterns

A warming trend began in May 1961, and above-normal temperatures continued throughout the summer months. Associated with the warm weather was an upper level air-flow pattern in which a strong high-pressure ridge hovered over western North America. This affected the belt of westerlies and the jet-stream axis by pushing them far into northern Canada. With such an orientation of ridges and wind patterns, little frontal movement developed, and cool Pacific air masses could not penetrate.

In mid-June a combination of unusual weather features caused a blistering week-long heat wave in central California.[1] First, the usual southwestern thermal low pressure extended into northern California. This movement brought in a light northerly surface flow of dry, adiabatically-warmed air to the central valley from the western interior. Next, along with the thermal low, a high pressure ridge aloft introduced warm air from the south and southwest. The subsiding air mass aloft increased its heat content and thereby left skies clear for maximum solar radiation to reach the earth. Air temperatures up to 115°F. were common and killed much of the spring plant growth to an elevation of 2,500 feet, drastically raising the fire danger.

1/ Ludlum, David L. Weatherwatch. Weatherwise 14(4):162-167, illus. 1961.


Mount Shasta
Eureka
Alturas
Truckee
Placerville
Ukiah
North Fork
Arroyo Seco
San Bernardino
San Diego
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'57 '58 '59 '60 '61

Figure 1.--Annual precipitation for a five-year period in 10 selected areas.

The warm pattern was broken temporarily in late July as the ridge moved off the coast, but it returned strongly again in August. Also in August, the moist tongue of air which normally extends from the Gulf of Mexico across the Southwest this time of the year shifted westward, causing an unusually large number of lightning storms in California.

Another major change in the high-pressure upper-level flow pattern took place in September. The ridge in western North America was replaced by a low-pressure trough, and a ridge developed over the eastern Pacific. This smaller amplitude pattern with more zonal flow continued for the rest of the fire season. It allowed cool Pacific air masses to penetrate California, and lowered the temperature to near normal. The pattern allowed more frontal activity, particularly in northern and central California, and brought some precipitation to these areas. However, this pattern also allowed portions of the Pacific high pressure cell to break off and move into the Great Basin. High pressure in the Great Basin produces drying north to east winds in California, and dry winds recurred periodically throughout the fall months--around Labor Day, October 1, and November 6 and 13.

Fire Weather Severity

The relative severity of the fire weather for 1961 can be shown by the wildland fire danger rating system, which includes five basic indexes: (1) spread index, which measures how fast a fire will spread; (2) intensity index, which measures how hot a fire will burn; (3) ignition index, which measures the relative ignitability of fine forest fuels and thereby also indicates the spotting potential of a fire; (4) burning index, which combines the spread and intensity indexes to indicate the size of the potential control job for an individual fire; and (5) fire load index, which combines the ignition and burning indexes to indicate the magnitude of the total potential fire control job that may be expected by the fire control organization. The fire season severity for any desired period can be measured by cumulating the fire load index.

Ten representative areas were selected to show the fire season severity throughout California (fig. 2). The fire weather severity in nearly all fire danger rating areas exceeded average conditions, as it also did in 1960 (table 1). Only in northern California did the severity fall below conditions in 1960. In central and southern California, it exceeded the normal by a wide margin. In the 4-month period from June through September, some areas had almost twice the normal fire weather severity. The highest departure from normal appeared in the foothill area on the west side of the San Joaquin Valley which had a fire weather severity more than three times the average.

Peaks of extreme fire danger are reflected in the large fires and heavy damages in 1961. Major losses occurred during early July in the Mariposa fire danger rating area in central California. Four fires burned a total of about 110,000 acres when indexes peaked into the extreme ranges (fig. 3).

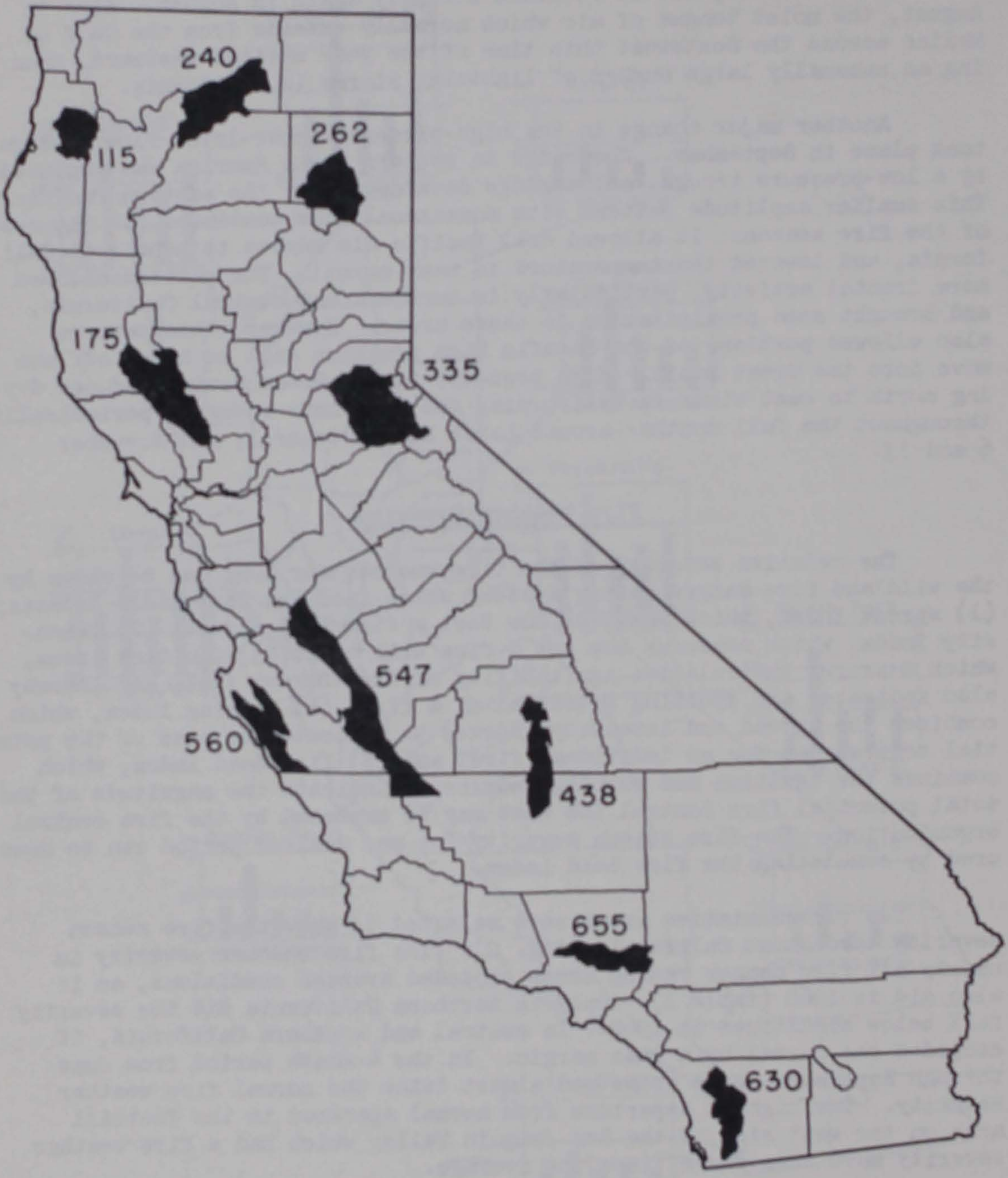
240
262
115
175
335
547
560
438
655
630

Figure 2.--Location of 10 representative areas used to rate seasonal fire weather severity.

Table 1.--California fire weather severity ratings, June 1 - Sept. 30, by 10 representative fire danger rating areas

Fire danger rating area		Ratio to normal		Actual severity		
Name	Number	1960	1961	Normal	1960	1961
Clear Lake - Berryessa	175	(1/)	2.10	1,130	(1/)	2,370
Eagle Lake	262	(1/)	1.64	1,800	(1/)	2,960
Mount Shasta	240	1.71	1.34	1,042	1,779	1,399
Pacific	335	1.97	1.83	912	1,797	1,671
San Diego	630	(1/)	1.73	852	(1/)	1,470
San Gabriel Mountains	655	1.86	1.76	1,218	2,263	2,140
Santa Lucia Range	560	1.32	1.44	1,509	1,997	2,175
Springville - Hot Springs	438	1.71	1.93	1,163	1,985	2,249
Westside San Joaquin Valley	547	(1/)	3.33	1,174	(1/)	3,910
Willow Creek	115	1.80	1.14	631	1,134	718

1/ Not available.

North of the Mariposa area, near the town of Copperopolis, the Highway 4 - #1 fire started on July 9. During the peak of unfavorable weather two days later, this fire blew up from 11,500 acres to 24,120 acres in a few hours. At the same time, the Harlow fire in the Mariposa area also "exploded" from 7,500 to 37,000 acres in one afternoon. Humidities of 11 and 12 percent and temperatures in the 100-110°F. range helped drop fuel moisture down to record lows of 2 and 2½ percent. Under these conditions, dry fuels can easily be ignited and fires spread even faster owing to spotting because of low fuel moistures. The ignition index during this period rose to 94 (fig. 3).

Severe fire weather again hit California over the long Labor Day weekend. A portion of the Pacific high pressure cell swept east into the Great Basin and brought strong, dry north to east winds in California. The lower fuel moistures and high winds boosted the burning indexes (figs. 4, 5, 6). As the fire weather became more severe, so did fire damage. From August 31 to September 7, about 185,000 acres of wildland and a hundred structures were burned in 500 fires.

The final period of extreme fire weather during the 1961 season was the most damaging because many homes were destroyed. The low humidities, low fuel moisture, and high winds resulted in some of the highest fire danger indexes on record (table 2). In November the Bel-Air,

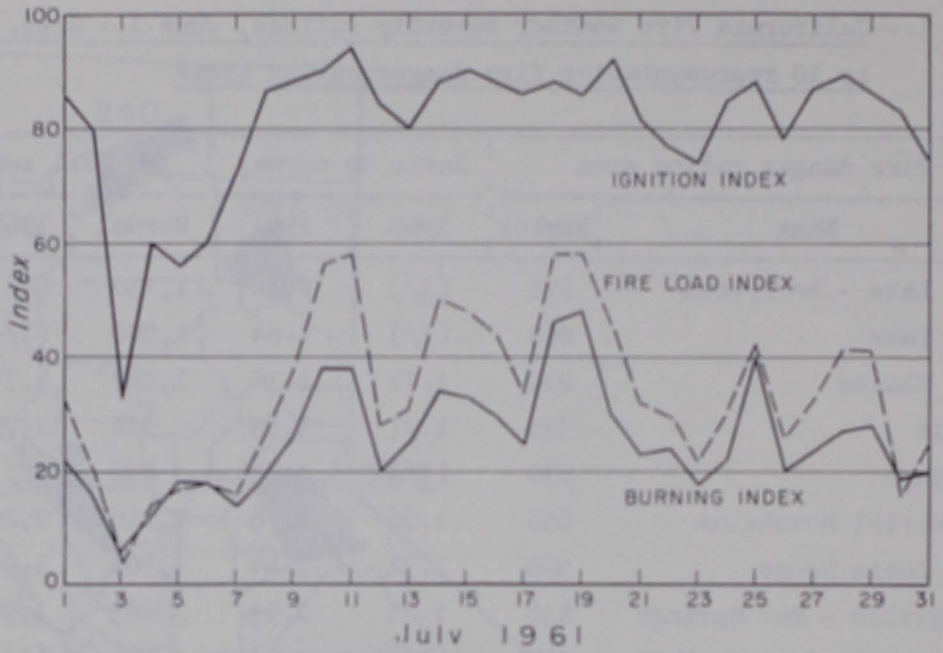

Figure 3.--Daily fire danger during July 1961 in the Mariposa fire rating area.

Brentwood, and Topanga fires raged across 14,800 acres in the Santa Monica Mountains and destroyed 456 structures. The heavy losses were attributed to fire behavior, poor home location, and brush fuel accumulations next to buildings.

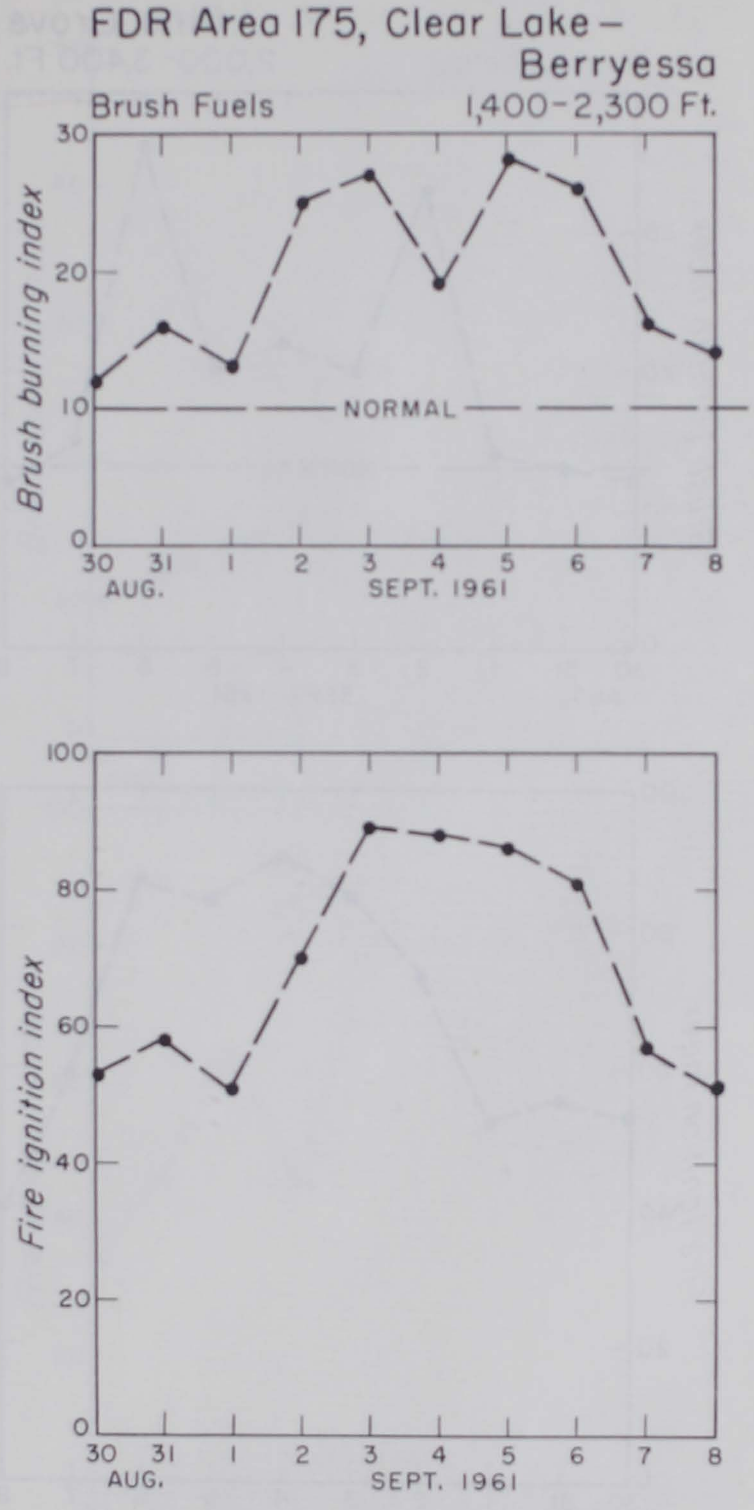

Figure 4.--Peak fire danger during Labor Day weekend.

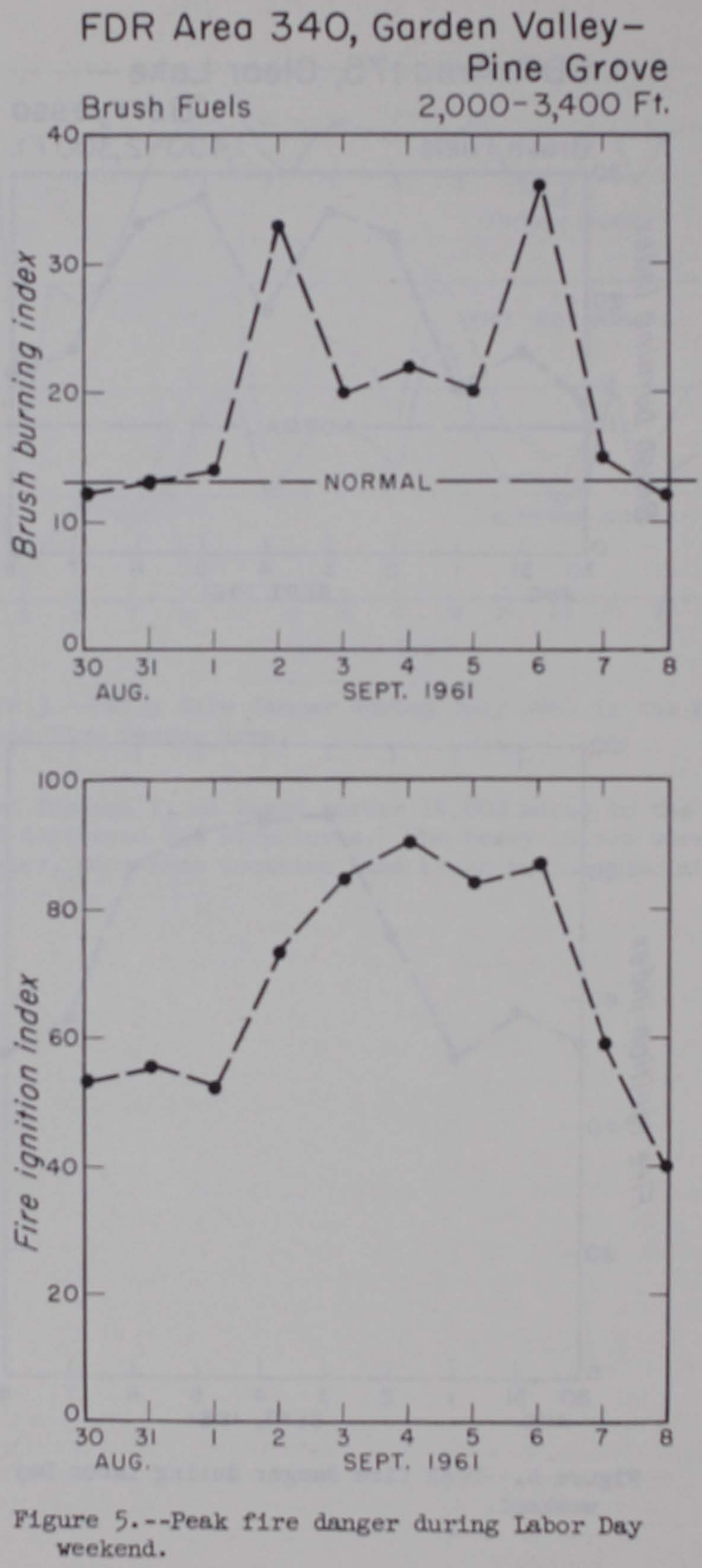

Figure 5.--Peak fire danger during Labor Day weekend.

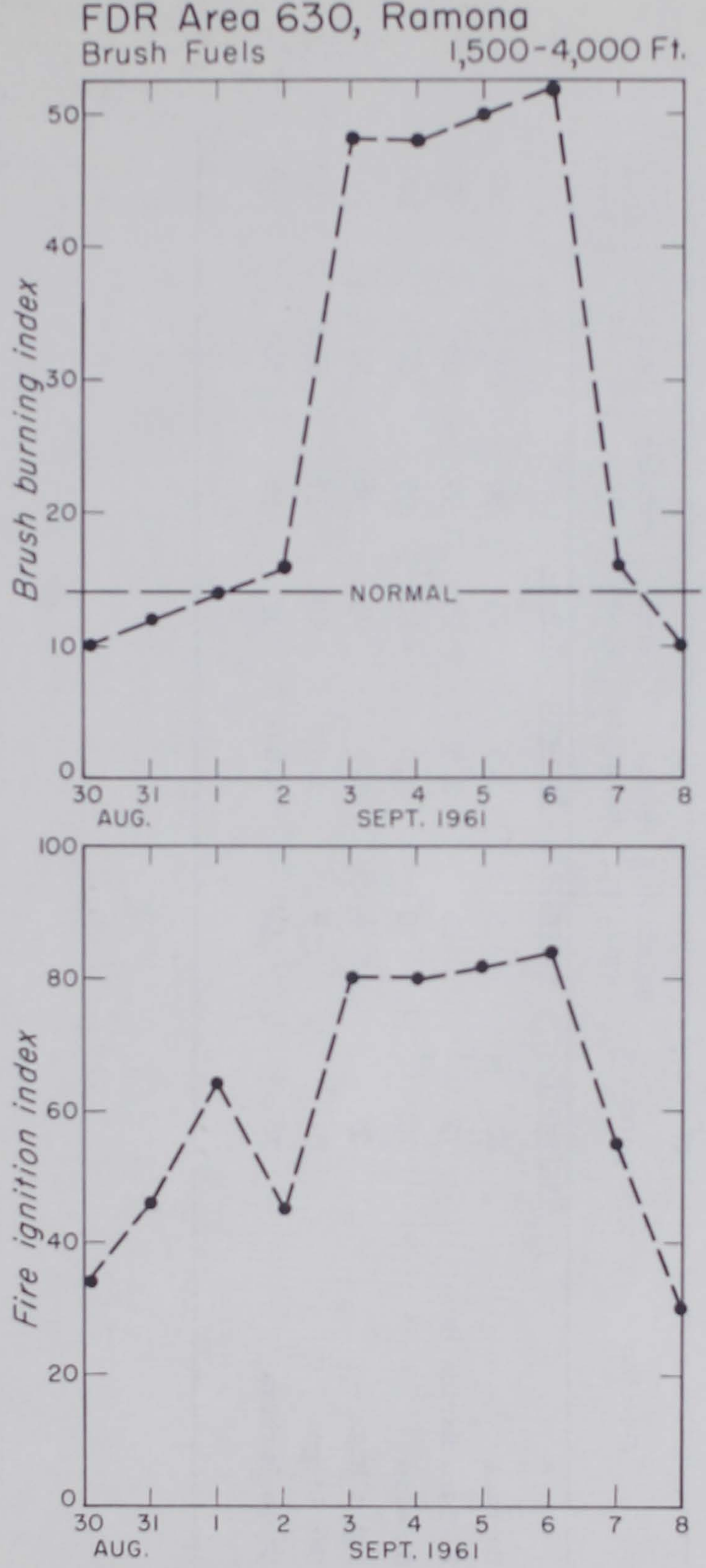

Figure 6.--Peak fire danger during Labor Day weekend.

Table 2.--Weather conditions at 2 p.m., November 6, 1961, and fire indexes, by selected stations in southern California

Station	Temperature	Relative humidity	Fuel moisture	Wind speed	Burning index	Ignition index	Fire load index
	Degrees F.	Percent	Percent	M.p.h.			
Burbank	81	5	1.5	23	96	95	100
El Toro Marine Base	79	12	2.5	25	99	88	100
Ontario	76	10	3.0	40	95	88	100
Point Mugu	88	4	1.5	23	96	95	100
San Diego	81	9	1.5	10	37	95	60
Santa Barbara	78	11	3.0	17	58	88	80

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No. 71

1962

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FOREST PRODUCTS HARVESTED IN HAWAII: 1958 AND 1960

By

Robert E. Nelson
Research Forester

Primary products from Hawaii's forests support small but locally important manufacturing industries. These products include craftwood, fuelwood, posts, sawlogs, treefern, and veneer logs. They provide about 1 percent of the 100 million board feet of wood used in Hawaii each year. The volume of log production increased between 1958 and 1960, according to a survey by the Forestry Division of the Hawaii Department of Land and Natural Resources, but the value of harvested products decreased because of a local shortage of the valuable monkey-pod.[1]

The Forestry Division sent questionnaires to all known producers of forest products in Hawaii. District foresters made some followup contacts to clarify possibly ambiguous questions and to query nonrespondents. This paper summarizes data compiled from questionnaires returned by 40 producers in 1958 and 26 producers in 1960. It includes estimates of the production of two nonrespondents in 1958 and three nonrespondents in 1960. The Division plans future surveys and will report findings periodically.

Results

The value of forest products harvested in 1960 was 73 percent of the value in 1958. This decline occurred even though total log production (craftwood, sawlogs, veneer logs) expanded. The main decrease was in the production of monkey-pod craft logs. There were fewer producers of monkey-pod logs and fence posts in 1960.

The volume of sawlogs harvested in 1960 was more than double that in 1958. Production of eucalyptus and koa logs rose sharply. But unit value dipped 33 percent. This drop is partly due to the increased volume of eucalyptus logs, which were harvested at less cost than were koa and ohia. The differences in unit value may have developed because of different interpretations of value between the two years.

---

[1] A cooperative study by the Hawaii Forestry Division and the U.S. Forest Service.

Table 1.--Estimated total production, total value, and average unit value of primary forest products in Hawaii, 1958 and 1960[1]

Primary forest product	Estimated total production			Estimated total value[2]		Average unit value	
	Unit of measure	1958	1960	1958	1960	1958	1960
Sawlogs	1,000 board feet	405	850	$ 40,000	$57,000	$100.00	$67.00
Craftwood	1,000 board feet	510	100	121,000	20,000	235.00	200.00
Veneer logs	1,000 board feet	(3/)	30	(3/)	9,000	(3/)	300.00
Fuelwood	Cords	1,300	1,500	19,000	45,000	14.50	30.00
Posts	Pieces	65,000	37,000	54,000	22,000	0.83	0.60
Treefern	Cubic feet	100,000	115,000	35,000	44,000	0.35	0.38
Totals	----------	-----	-----	$269,000	$197,000	-----	-----

[1] From surveys by the Forestry Division of the Hawaii Department of Land and Natural Resources.

[2] Based on products cut and hauled out of the forest but not further processed. The value of consumer products manufactured from this raw material is many times greater.

[3] None reported.

The harvest of craftwood logs, mostly koa, in 1960 is estimated as only one-fifth of 1958 production. Demand for craft items has risen as tourist trade in Hawaii has increased. But the local supply of choice species--monkey-pod--is almost exhausted. In 1959 most craft producers began to import monkey-pod logs from Fiji and other areas. The unit value of craftwood has decreased because of species; koa does not demand the price that buyers will pay for monkey-pod.

The 1958 survey did not reveal any veneer log production, although in past years and since then koa logs have been cut and shipped to the United States mainland and to Japan. The 30,000 board feet of veneer logs harvested in 1960 were exported.

Fuelwood cutting, mostly for charcoal, increased by about 10 percent between 1958 and 1960. The reported increase in unit value between the two years may be the result of different interpretations by respondents. This almost doubled unit value does not appear realistic.

Production of fence posts dropped 40 percent in 2 years. Differences in production and unit value data may not be significant since detailed records are seldom kept, especially by ranchers who cut their own posts.

Between 1958 and 1960, production, total value, and unit value of treefern all showed increases. Production jumped about 15 percent. Mainland markets were expanded, and harvesters received higher prices for fern logs.

Conclusions

Data from the two surveys are not adequate for establishing long-term trends in local forest production, but they do show the relative importance of products. It is apparent, that:

1. Eucalyptus lumber is finding a small but growing market owing to the efforts of pioneers in the industry.

2. Craft producers have turned to offshore sources for the highly valued monkey-pod logs because of inadequate local supply. But local production of finished craft items probably increased.

3. Treefern logs support an appreciable segment of the forest products manufacturing industry.

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No. 72 1962

BASAL AREA TABLE FOR DIAMETERS FROM 1 TO 240 INCHES BY TENTH-INCH CLASSES

By

David C. Galant and Douglass F. Roy

The basal area of a tree is the cross-sectional area of the stem at 4.5 feet above the ground. In the United States, basal area customarily is calculated in square feet from the diameter outside bark.[1] In young fully stocked stands, basal area increases rapidly, but it levels off as the stands mature and usually does not increase in later years. Consequently, total basal area of the trees on a forest unit often is used as a measure of stocking, and is considered as the best single criterion for evaluating this attribute.

Basal area also has other uses. One example is in calculating mean diameter of the trees in a forest stand, the average diameter being defined as the diameter of a tree having the average basal area.

Many basal area tables have been published, but none of those readily available lists areas for diameters larger than 60 inches; hence, published tables are seldom useful for stands of large trees such as the redwoods (Sequoia sempervirens (D. Don) Endl.) in California. Furthermore, some of the old tables were developed by reading curves and, although entirely satisfactory as a working tool, are not finely accurate.

The basal area table published here includes basal areas of circles from 1 to 240 inches in diameter. Table entries were calculated by an electronic computer using 3.141592654 for the value of pi.

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[1] Meyer, Arthur B., and Eyre, F. H., editors. Forest terminology. Ed. 3, 97 pp. Soc. Amer. Foresters, Wash., D. C. 1958. (This edition of Forest Terminology incorrectly states that basal area is usually computed for the cross section inside bark unless otherwise stated.)

Table of basal area in square feet by .1 inch increment of diameter breast height from 1 inch to 240 inches

	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
1	.0055	.0066	.0079	.0092	.0107	.0123	.0140	.0158	.0177	.0197
2	.0218	.0241	.0264	.0289	.0314	.0341	.0369	.0398	.0428	.0459
3	.0491	.0524	.0559	.0594	.0631	.0668	.0707	.0747	.0788	.0830
4	.0873	.0917	.0962	.1008	.1056	.1104	.1154	.1205	.1257	.1310
5	.1364	.1419	.1475	.1532	.1590	.1650	.1710	.1772	.1835	.1899
6	.1963	.2029	.2097	.2165	.2234	.2304	.2376	.2448	.2522	.2597
7	.2673	.2749	.2827	.2907	.2987	.3068	.3150	.3234	.3318	.3404
8	.3491	.3578	.3667	.3757	.3848	.3941	.4034	.4128	.4224	.4320
9	.4418	.4517	.4616	.4717	.4819	.4922	.5027	.5132	.5238	.5346
10	.5454	.5564	.5675	.5786	.5899	.6013	.6128	.6244	.6362	.6480
11	.6600	.6720	.6842	.6964	.7088	.7213	.7339	.7466	.7594	.7724
12	.7854	.7985	.8118	.8252	.8386	.8522	.8659	.8797	.8936	.9076
13	.9218	.9360	.9503	.9648	.9793	.9940	1.0088	1.0237	1.0387	1.0538
14	1.0690	1.0843	1.0998	1.1153	1.1310	1.1467	1.1626	1.1786	1.1947	1.2109
15	1.2272	1.2436	1.2601	1.2768	1.2935	1.3104	1.3273	1.3444	1.3616	1.3789
16	1.3963	1.4138	1.4314	1.4491	1.4669	1.4849	1.5029	1.5211	1.5394	1.5578
17	1.5763	1.5948	1.6136	1.6324	1.6513	1.6703	1.6895	1.7087	1.7281	1.7476
18	1.7671	1.7868	1.8066	1.8265	1.8466	1.8667	1.8869	1.9073	1.9277	1.9483
19	1.9689	1.9897	2.0106	2.0316	2.0527	2.0739	2.0953	2.1167	2.1382	2.1599
20	2.1817	2.2035	2.2255	2.2476	2.2698	2.2921	2.3145	2.3371	2.3597	2.3824
21	2.4053	2.4282	2.4513	2.4745	2.4978	2.5212	2.5447	2.5683	2.5920	2.6159
22	2.6398	2.6639	2.6880	2.7123	2.7367	2.7612	2.7858	2.8105	2.8353	2.8602
23	2.8852	2.9104	2.9356	2.9610	2.9865	3.0121	3.0377	3.0635	3.0895	3.1155
24	3.1416	3.1678	3.1942	3.2206	3.2472	3.2739	3.3006	3.3275	3.3545	3.3816
25	3.4088	3.4362	3.4636	3.4911	3.5188	3.5466	3.5744	3.6024	3.6305	3.6587

Table of basal area in square feet by .1 inch increment of diameter breast height from 1 inch to 240 inches—Con.

	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
26	3.6870	3.7154	3.7439	3.7726	3.8013	3.8302	3.8591	3.8882	3.9174	3.9467
27	3.9761	4.0056	4.0352	4.0649	4.0948	4.1247	4.1548	4.1849	4.2152	4.2456
28	4.2761	4.3067	4.3374	4.3682	4.3991	4.4301	4.4613	4.4925	4.5239	4.5554
29	4.5869	4.6186	4.6504	4.6823	4.7144	4.7465	4.7787	4.8111	4.8435	4.8761
30	4.9087	4.9415	4.9744	5.0074	5.0405	5.0737	5.1071	5.1405	5.1740	5.2077
31	5.2414	5.2753	5.3093	5.3434	5.3776	5.4119	5.4463	5.4808	5.5155	5.5502
32	5.5851	5.6200	5.6551	5.6903	5.7256	5.7610	5.7965	5.8321	5.8678	5.9036
33	5.9396	5.9756	6.0118	6.0481	6.0844	6.1209	6.1575	6.1942	6.2310	6.2680
34	6.3050	6.3421	6.3794	6.4168	6.4542	6.4918	6.5295	6.5673	6.6052	6.6432
35	6.6813	6.7196	6.7579	6.7964	6.8349	6.8736	6.9124	6.9513	6.9903	7.0294
36	7.0686	7.1079	7.1473	7.1869	7.2265	7.2663	7.3062	7.3461	7.3862	7.4264
37	7.4667	7.5072	7.5477	7.5883	7.6291	7.6699	7.7109	7.7519	7.7931	7.8344
38	7.8758	7.9173	7.9589	8.0006	8.0425	8.0844	8.1265	8.1686	8.2109	8.2533
39	8.2958	8.3384	8.3811	8.4239	8.4668	8.5098	8.5530	8.5962	8.6396	8.6831
40	8.7266	8.7703	8.8141	8.8580	8.9021	8.9462	8.9904	9.0348	9.0792	9.1238
41	9.1684	9.2132	9.2581	9.3031	9.3482	9.3934	9.4387	9.4842	9.5297	9.5754
42	9.6211	9.6670	9.7130	9.7591	9.8053	9.8516	9.8980	9.9445	9.9911	10.0379
43	10.0847	10.1317	10.1788	10.2259	10.2732	10.3206	10.3681	10.4157	10.4635	10.5113
44	10.5592	10.6073	10.6555	10.7037	10.7521	10.8006	10.8492	10.8979	10.9467	10.9956
45	11.0447	11.0938	11.1431	11.1924	11.2419	11.2915	11.3412	11.3909	11.4409	11.4909
46	11.5410	11.5912	11.6416	11.6920	11.7426	11.7932	11.8440	11.8949	11.9459	11.9970
47	12.0482	12.0996	12.1510	12.2025	12.2542	12.3059	12.3578	12.4098	12.4619	12.5141
48	12.5664	12.6188	12.6713	12.7239	12.7767	12.8295	12.8825	12.9356	12.9887	13.0420
49	13.0954	13.1489	13.2025	13.2563	13.3101	13.3640	13.4181	13.4723	13.5265	13.5809
50	13.6354	13.6900	13.7447	13.7995	13.8544	13.9095	13.9646	14.0198	14.0752	14.1307

Table of basal area in square feet by .1 inch increment of diameter breast height from 1 inch to 240 inches—Con.

	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
51	14.1863	14.2419	14.2977	14.3536	14.4097	14.4658	14.5220	14.5784	14.6348	14.6914
52	14.7480	14.8048	14.8617	14.9187	14.9758	15.0330	15.0903	15.1478	15.2053	15.2630
53	15.3207	15.3786	15.4366	15.4947	15.5528	15.6112	15.6696	15.7281	15.7867	15.8455
54	15.9043	15.9633	16.0223	16.0815	16.1408	16.2002	16.2597	16.3193	16.3790	16.4389
55	16.4988	16.5589	16.6190	16.6793	16.7397	16.8002	16.8608	16.9215	16.9823	17.0432
56	17.1042	17.1654	17.2266	17.2880	17.3494	17.4110	17.4727	17.5345	17.5964	17.6584
57	17.7205	17.7828	17.8451	17.9076	17.9701	18.0328	18.0956	18.1585	18.2215	18.2846
58	18.3478	18.4111	18.4745	18.5381	18.6017	18.6655	18.7293	18.7933	18.8574	18.9216
59	18.9859	19.0503	19.1148	19.1795	19.2442	19.3091	19.3740	19.4391	19.5043	19.5696
60	19.6350	19.7005	19.7661	19.8318	19.8976	19.9636	20.0296	20.0958	20.1620	20.2284
61	20.2949	20.3615	20.4282	20.4950	20.5619	20.6290	20.6961	20.7634	20.8307	20.8982
62	20.9658	21.0335	21.1012	21.1692	21.2372	21.3053	21.3735	21.4419	21.5103	21.5789
63	21.6475	21.7163	21.7852	21.8542	21.9233	21.9925	22.0618	22.1313	22.2008	22.2705
64	22.3402	22.4101	22.4801	22.5501	22.6203	22.6906	22.7611	22.8316	22.9022	22.9730
65	23.0438	23.1148	23.1858	23.2570	23.3283	23.3997	23.4712	23.5428	23.6145	23.6864
66	23.7583	23.8303	23.9025	23.9748	24.0471	24.1196	24.1922	24.2649	24.3377	24.4107
67	24.4837	24.5568	24.6301	24.7034	24.7769	24.8505	24.9242	24.9980	25.0719	25.1459
68	25.2200	25.2942	25.3686	25.4430	25.5176	25.5923	25.6670	25.7419	25.8169	25.8920
69	25.9672	26.0425	26.1180	26.1935	26.2692	26.3449	26.4208	26.4968	26.5729	26.6491
70	26.7254	26.8018	26.8783	26.9549	27.0317	27.1085	27.1855	27.2625	27.3397	27.4170
71	27.4944	27.5719	27.6495	27.7272	27.8051	27.8830	27.9610	28.0392	28.1175	28.1958
72	28.2743	28.3529	28.4316	28.5104	28.5894	28.6684	28.7475	28.8268	28.9061	28.9856
73	29.0652	29.1449	29.2247	29.3046	29.3846	29.4647	29.5449	29.6253	29.7057	29.7863
74	29.8669	29.9477	30.0286	30.1096	30.1907	30.2719	30.3532	30.4347	30.5162	30.5979
75	30.6796	30.7615	30.8435	30.9255	31.0077	31.0900	31.1725	31.2550	31.3376	31.4203

Table of basal area in square feet by .1 inch increment of diameter breast height from 1 inch to 240 inches—Con.

	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
76	31.5032	31.5862	31.6692	31.7524	31.8357	31.9191	32.0026	32.0862	32.1699	32.2537
77	32.3377	32.4217	32.5059	32.5902	32.6745	32.7590	32.8436	32.9283	33.0131	33.0980
78	33.1831	33.2682	33.3535	33.4388	33.5243	33.6099	33.6955	33.7813	33.8672	33.9533
79	34.0394	34.1256	34.2119	34.2984	34.3850	34.4716	34.5584	34.6453	34.7323	34.8194
80	34.9066	34.9939	35.0813	35.1689	35.2565	35.3443	35.4321	35.5201	35.6082	35.6964
81	35.7847	35.8731	35.9616	36.0503	36.1390	36.2279	36.3168	36.4059	36.4951	36.5843
82	36.6737	36.7632	36.8528	36.9426	37.0324	37.1223	37.2124	37.3025	37.3928	37.4832
83	37.5737	37.6643	37.7550	37.8458	37.9367	38.0277	38.1189	38.2101	38.3015	38.3929
84	38.4845	38.5762	38.6680	38.7599	38.8519	38.9440	39.0363	39.1286	39.2210	39.3136
85	39.4063	39.4990	39.5919	39.6849	39.7780	39.8712	39.9646	40.0580	40.1515	40.2452
86	40.3389	40.4328	40.5268	40.6208	40.7150	40.8093	40.9038	40.9983	41.0929	41.1876
87	41.2825	41.3774	41.4725	41.5677	41.6630	41.7584	41.8539	41.9495	42.0452	42.1410
88	42.2370	42.3330	42.4292	42.5254	42.6218	42.7183	42.8149	42.9116	43.0084	43.1053
89	43.2024	43.2995	43.3967	43.4941	43.5916	43.6891	43.7868	43.8846	43.9825	44.0805
90	44.1786	44.2769	44.3752	44.4737	44.5722	44.6709	44.7697	44.8685	44.9675	45.0666
91	45.1658	45.2652	45.3646	45.4641	45.5638	45.6635	45.7634	45.8634	45.9635	46.0637
92	46.1640	46.2644	46.3649	46.4655	46.5663	46.6671	46.7681	46.8691	46.9703	47.0716
93	47.1730	47.2745	47.3761	47.4778	47.5796	47.6816	47.7836	47.8858	47.9880	48.0904
94	48.1929	48.2955	48.3982	48.5010	48.6039	48.7070	48.8101	48.9133	49.0167	49.1202
95	49.2237	49.3274	49.4312	49.5351	49.6391	49.7432	49.8475	49.9518	50.0563	50.1608
96	50.2655	50.3703	50.4751	50.5801	50.6852	50.7904	50.8958	51.0012	51.1067	51.2124
97	51.3181	51.4240	51.5300	51.6361	51.7423	51.8486	51.9550	52.0615	52.1681	52.2748
98	52.3817	52.4887	52.5957	52.7029	52.8102	52.9176	53.0251	53.1327	53.2404	53.3482
99	53.4562	53.5642	53.6724	53.7806	53.8890	53.9975	54.1061	54.2148	54.3236	54.4325
100	54.5415	54.6507	54.7599	54.8693	54.9787	55.0883	55.1980	55.3078	55.4177	55.5277

Table of basal area in square feet by .1 inch increment of diameter breast height from 1 inch to 240 inches—Con.

	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
101	55.6378	55.7481	55.8584	55.9688	56.0794	56.1901	56.3008	56.4117	56.5227	56.6338
102	56.7450	56.8563	56.9678	57.0793	57.1910	57.3027	57.4146	57.5265	57.6386	57.7508
103	57.8631	57.9755	58.0880	58.2007	58.3134	58.4263	58.5392	58.6523	58.7655	58.8787
104	58.9921	59.1056	59.2192	59.3330	59.4468	59.5607	59.6748	59.7889	59.9032	60.0176
105	60.1320	60.2466	60.3613	60.4762	60.5911	60.7061	60.8212	60.9365	61.0518	61.1673
106	61.2829	61.3986	61.5143	61.6302	61.7463	61.8624	61.9786	62.0949	62.2114	62.3279
107	62.4446	62.5614	62.6783	62.7953	62.9124	63.0296	63.1469	63.2643	63.3819	63.4995
108	63.6173	63.7351	63.8531	63.9712	64.0894	64.2077	64.3261	64.4446	64.5632	64.6820
109	64.8008	64.9198	65.0388	65.1580	65.2773	65.3967	65.5162	65.6358	65.7555	65.8753
110	65.9953	66.1153	66.2355	66.3557	66.4761	66.5966	66.7172	66.8379	66.9587	67.0796
111	67.2006	67.3218	67.4430	67.5644	67.6858	67.8074	67.9291	68.0509	68.1728	68.2948
112	68.4169	68.5391	68.6615	68.7839	68.9065	69.0291	69.1519	69.2748	69.3978	69.5209
113	69.6441	69.7674	69.8908	70.0144	70.1380	70.2618	70.3856	70.5096	70.6337	70.7579
114	70.8822	71.0066	71.1311	71.2557	71.3805	71.5053	71.6303	71.7553	71.8805	72.0058
115	72.1312	72.2567	72.3823	72.5080	72.6338	72.7598	72.8858	73.0120	73.1382	73.2646
116	73.3911	73.5177	73.6444	73.7712	73.8981	74.0251	74.1523	74.2795	74.4069	74.5343
117	74.6619	74.7896	74.9174	75.0453	75.1733	75.3014	75.4296	75.5580	75.6864	75.8150
118	75.9436	76.0724	76.2013	76.3303	76.4594	76.5886	76.7179	76.8473	76.9769	77.1065
119	77.2363	77.3661	77.4961	77.6262	77.7564	77.8867	78.0171	78.1476	78.2782	78.4090
120	78.5398	78.6708	78.8018	78.9330	79.0643	79.1957	79.3272	79.4588	79.5905	79.7223
121	79.8543	79.9863	80.1185	80.2507	80.3831	80.5156	80.6482	80.7809	80.9137	81.0466
122	81.1796	81.3128	81.4460	81.5794	81.7128	81.8464	81.9801	82.1139	82.2478	82.3818
123	82.5159	82.6501	82.7845	82.9189	83.0535	83.1881	83.3229	83.4578	83.5928	83.7279
124	83.8631	83.9984	84.1338	84.2694	84.4050	84.5408	84.6766	84.8126	84.9487	85.0849
125	85.2212	85.3576	85.4941	85.6307	85.7674	85.9043	86.0412	86.1783	86.3155	86.4528

Table of basal area in square feet by .1 inch increment of diameter breast height from 1 inch to 240 inches—Con.

	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
126	86.5901	86.7276	86.8653	87.0030	87.1408	87.2787	87.4168	87.5549	87.6932	87.8316
127	87.9701	88.1086	88.2473	88.3861	88.5251	88.6641	88.8032	88.9425	89.0818	89.2213
128	89.3609	89.5005	89.6403	89.7802	89.9202	90.0604	90.2006	90.3409	90.4814	90.6219
129	90.7626	90.9033	91.0442	91.1852	91.3263	91.4675	91.6088	91.7503	91.8918	92.0334
130	92.1752	92.3171	92.4590	92.6011	92.7433	92.8856	93.0280	93.1705	93.3132	93.4559
131	93.5987	93.7417	93.8848	94.0279	94.1712	94.3146	94.4581	94.6017	94.7454	94.8892
132	95.0332	95.1772	95.3214	95.4656	95.6100	95.7545	95.8991	96.0438	96.1886	96.3335
133	96.4785	96.6237	96.7689	96.9143	97.0597	97.2053	97.3510	97.4968	97.6427	97.7887
134	97.9348	98.0810	98.2274	98.3738	98.5203	98.6670	98.8138	98.9607	99.1077	99.2547
135	99.4020	99.5493	99.6967	99.8442	99.9919	100.1396	100.2875	100.4355	100.5835	100.7317
136	100.8800	101.0284	101.1770	101.3256	101.4743	101.6232	101.7721	101.9212	102.0704	102.2196
137	102.3690	102.5185	102.6681	102.8178	102.9677	103.1176	103.2676	103.4178	103.5681	103.7184
138	103.8689	104.0195	104.1702	104.3210	104.4719	104.6230	104.7741	104.9253	105.0767	105.2281
139	105.3797	105.5314	105.6832	105.8351	105.9871	106.1392	106.2914	106.4438	106.5962	106.7488
140	106.9014	107.0542	107.2071	107.3601	107.5132	107.6664	107.8197	107.9731	108.1266	108.2803
141	108.4340	108.5879	108.7419	108.8960	109.0501	109.2044	109.3588	109.5134	109.6680	109.8227
142	109.9776	110.1325	110.2876	110.4428	110.5980	110.7534	110.9089	111.0645	111.2202	111.3761
143	111.5320	111.6880	111.8442	112.0005	112.1568	112.3133	112.4699	112.6266	112.7834	112.9403
144	113.0973	113.2545	113.4117	113.5691	113.7265	113.8841	114.0418	114.1996	114.3575	114.5155
145	114.6736	114.8318	114.9902	115.1486	115.3071	115.4658	115.6246	115.7835	115.9424	116.1015
146	116.2608	116.4201	116.5795	116.7390	116.8987	117.0584	117.2183	117.3783	117.5383	117.6985
147	117.8588	118.0192	118.1797	118.3404	118.5011	118.6619	118.8229	118.9840	119.1451	119.3064
148	119.4678	119.6293	119.7909	119.9526	120.1144	120.2764	120.4384	120.6006	120.7628	120.9252
149	121.0877	121.2503	121.4130	121.5758	121.7387	121.9017	122.0648	122.2281	122.3914	122.5549
150	122.7185	122.8821	123.0459	123.2098	123.3738	123.5380	123.7022	123.8665	124.0310	124.1955

Table of basal area in square feet by .1 inch increment of diameter breast height from 1 inch to 240 inches—Con.

	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
151	124.3602	124.5249	124.6898	124.8548	125.0199	125.1851	125.3504	125.5159	125.6814	125.8470
152	126.0128	126.1786	126.3446	126.5107	126.6769	126.8432	127.0096	127.1761	127.3427	127.5095
153	127.6763	127.8432	128.0103	128.1775	128.3448	128.5121	128.6796	128.8472	129.0150	129.1828
154	129.3507	129.5188	129.6869	129.8552	130.0235	130.1920	130.3606	130.5293	130.6981	130.8670
155	131.0361	131.2052	131.3744	131.5438	131.7132	131.8828	132.0525	132.2223	132.3922	132.5622
156	132.7323	132.9025	133.0729	133.2433	133.4138	133.5845	133.7553	133.9262	134.0971	134.2682
157	134.4394	134.6108	134.7822	134.9537	135.1254	135.2971	135.4690	135.6409	135.8130	135.9852
158	136.1575	136.3299	136.5024	136.6751	136.8478	137.0206	137.1936	137.3666	137.5398	137.7131
159	137.8865	138.0600	138.2336	138.4073	138.5811	138.7550	138.9291	139.1032	139.2775	139.4519
160	139.6263	139.8009	139.9756	140.1504	140.3254	140.5004	140.6755	140.8508	141.0261	141.2016
161	141.3771	141.5528	141.7286	141.9045	142.0805	142.2566	142.4328	142.6092	142.7856	142.9622
162	143.1388	143.3156	143.4925	143.6695	143.8466	144.0238	144.2011	144.3785	144.5560	144.7337
163	144.9114	145.0893	145.2673	145.4453	145.6235	145.8018	145.9802	146.1587	146.3374	146.5161
164	146.6949	146.8739	147.0529	147.2321	147.4114	147.5908	147.7703	147.9499	148.1296	148.3094
165	148.4893	148.6694	148.8495	149.0298	149.2102	149.3906	149.5712	149.7519	149.9327	150.1136
166	150.2947	150.4758	150.6570	150.8384	151.0199	151.2014	151.3831	151.5649	151.7468	151.9288
167	152.1109	152.2931	152.4755	152.6579	152.8405	153.0231	153.2059	153.3888	153.5717	153.7548
168	153.9380	154.1214	154.3048	154.4883	154.6720	154.8557	155.0396	155.2235	155.4076	155.5918
169	155.7761	155.9605	156.1450	156.3296	156.5144	156.6992	156.8842	157.0692	157.2544	157.4397
170	157.6251	157.8106	157.9962	158.1819	158.3677	158.5536	158.7397	158.9258	159.1121	159.2984
171	159.4849	159.6715	159.8582	160.0450	160.2319	160.4189	160.6061	160.7933	160.9807	161.1681
172	161.3557	161.5434	161.7312	161.9191	162.1071	162.2952	162.4834	162.6717	162.8602	163.0487
173	163.2374	163.4261	163.6150	163.8040	163.9931	164.1823	164.3716	164.5610	164.7506	164.9402
174	165.1300	165.3198	165.5098	165.6999	165.8901	166.0804	166.2708	166.4613	166.6519	166.8426
175	167.0335	167.2244	167.4155	167.6066	167.7979	167.9893	168.1808	168.3724	168.5641	168.7559

Table of basal area in square feet by .1 inch increment of diameter breast height from 1 inch to 240 inches—Con.

	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
176	168.9479	169.1399	169.3321	169.5243	169.7167	169.9092	170.1018	170.2945	170.4873	170.6802
177	170.8732	171.0663	171.2596	171.4529	171.6464	171.8399	172.0336	172.2274	172.4213	172.6153
178	172.8094	173.0036	173.1980	173.3924	173.5870	173.7816	173.9764	174.1713	174.3663	174.5613
179	174.7566	174.9519	175.1473	175.3428	175.5385	175.7342	175.9301	176.1260	176.3221	176.5183
180	176.7146	176.9110	177.1075	177.3041	177.5009	177.6977	177.8947	178.0917	178.2889	178.4862
181	178.6835	178.8810	179.0786	179.2764	179.4742	179.6721	179.8701	180.0683	180.2666	180.4649
182	180.6634	180.8620	181.0607	181.2595	181.4584	181.6574	181.8566	182.0558	182.2551	182.4546
183	182.6542	182.8538	183.0536	183.2535	183.4535	183.6536	183.8539	184.0542	184.2546	184.4552
184	184.6558	184.8566	185.0575	185.2585	185.4596	185.6608	185.8621	186.0635	186.2650	186.4667
185	186.6684	186.8703	187.0723	187.2743	187.4765	187.6788	187.8812	188.0837	188.2863	188.4891
186	188.6919	188.8949	189.0979	189.3011	189.5044	189.7078	189.9112	190.1149	190.3186	190.5224
187	190.7263	190.9304	191.1345	191.3388	191.5431	191.7476	191.9522	192.1569	192.3617	192.5666
188	192.7716	192.9768	193.1820	193.3873	193.5928	193.7984	194.0040	194.2098	194.4157	194.6217
189	194.8278	195.0341	195.2404	195.4468	195.6534	195.8600	196.0668	196.2737	196.4807	196.6878
190	196.8950	197.1023	197.3097	197.5172	197.7249	197.9326	198.1405	198.3484	198.5565	198.7647
191	198.9730	199.1814	199.3899	199.5985	199.8073	200.0161	200.2251	200.4341	200.6433	200.8526
192	201.0619	201.2714	201.4810	201.6907	201.9006	202.1105	202.3205	202.5307	202.7409	202.9513
193	203.1618	203.3724	203.5831	203.7939	204.0048	204.2158	204.4269	204.6382	204.8495	205.0610
194	205.2725	205.4842	205.6960	205.9079	206.1199	206.3320	206.5442	206.7566	206.9690	207.1816
195	207.3942	207.6070	207.8199	208.0328	208.2459	208.4591	208.6724	208.8859	209.0994	209.3130
196	209.5268	209.7406	209.9546	210.1687	210.3829	210.5972	210.8116	211.0261	211.2407	211.4554
197	211.6703	211.8852	212.1003	212.3154	212.5307	212.7461	212.9616	213.1772	213.3929	213.6087
198	213.8247	214.0407	214.2568	214.4731	214.6895	214.9059	215.1225	215.3392	215.5560	215.7729
199	215.9900	216.2071	216.4243	216.6417	216.8591	217.0767	217.2944	217.5122	217.7301	217.9481
200	218.1662	218.3844	218.6027	218.8212	219.0397	219.2584	219.4771	219.6960	219.9150	220.1341

Table of basal area in square feet by .1 inch increment of diameter breast height from 1 inch to 240 inches—Con.

	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
201	220.3533	220.5726	220.7920	221.0115	221.2312	221.4509	221.6708	221.8908	222.1108	222.3310
202	222.5513	222.7717	222.9922	223.2128	223.4336	223.6544	223.8754	224.0964	224.3176	224.5389
203	224.7602	224.9817	225.2033	225.4250	225.6469	225.8688	226.0908	226.3130	226.5352	226.7576
204	226.9801	227.2027	227.4254	227.6482	227.8711	228.0941	228.3172	228.5405	228.7638	228.9873
205	229.2108	229.4345	229.6583	229.8822	230.1062	230.3303	230.5545	230.7788	231.0033	231.2278
206	231.4525	231.6772	231.9021	232.1271	232.3522	232.5774	232.8027	233.0281	233.2537	233.4793
207	233.7050	233.9309	234.1569	234.3829	234.6091	234.8354	235.0618	235.2883	235.5150	235.7417
208	235.9685	236.1955	236.4225	236.6497	236.8770	237.1044	237.3318	237.5594	237.7872	238.0150
209	238.2429	238.4709	238.6991	238.9273	239.1557	239.3842	239.6128	239.8415	240.0703	240.2992
210	240.5282	240.7573	240.9866	241.2159	241.4454	241.6749	241.9046	242.1344	242.3643	242.5943
211	242.8244	243.0546	243.2849	243.5154	243.7459	243.9766	244.2074	244.4382	244.6692	244.9003
212	245.1315	245.3628	245.5942	245.8258	246.0574	246.2891	246.5210	246.7530	246.9850	247.2172
213	247.4495	247.6819	247.9144	248.1470	248.3798	248.6126	248.8456	249.0786	249.3118	249.5451
214	249.7784	250.0119	250.2455	250.4792	250.7131	250.9470	251.1810	251.4152	251.6494	251.8838
215	252.1183	252.3529	252.5875	252.8224	253.0573	253.2923	253.5274	253.7626	253.9980	254.2334
216	254.4690	254.7047	254.9405	255.1764	255.4124	255.6485	255.8847	256.1210	256.3575	256.5940
217	256.8307	257.0674	257.3043	257.5413	257.7784	258.0156	258.2529	258.4903	258.7278	258.9655
218	259.2032	259.4411	259.6790	259.9171	260.1553	260.3936	260.6320	260.8705	261.1091	261.3478
219	261.5867	261.8256	262.0647	262.3039	262.5431	262.7825	263.0220	263.2616	263.5013	263.7411
220	263.9811	264.2211	264.4612	264.7015	264.9419	265.1823	265.4229	265.6636	265.9044	266.1453
221	266.3863	266.6275	266.8687	267.1101	267.3515	267.5931	267.8347	268.0765	268.3184	268.5604
222	268.8025	269.0447	269.2871	269.5295	269.7721	270.0147	270.2575	270.5004	270.7433	270.9864
223	271.2296	271.4729	271.7164	271.9599	272.2035	272.4473	272.6911	272.9351	273.1792	273.4233
224	273.6676	273.9120	274.1565	274.4012	274.6459	274.8907	275.1357	275.3807	275.6259	275.8712
225	276.1166	276.3620	276.6076	276.8534	277.0992	277.3451	277.5911	277.8373	278.0835	278.3299

Table of basal area in square feet by .1 inch increment of diameter breast height from 1 inch to 240 inches—Con.

	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
226	278.5764	278.8230	279.0696	279.3164	279.5634	279.8104	280.0575	280.3047	280.5521	280.7995
227	281.0471	281.2948	281.5426	281.7905	282.0385	282.2866	282.5348	282.7831	283.0315	283.2801
228	283.5287	283.7775	284.0264	284.2754	284.5245	284.7737	285.0230	285.2724	285.5219	285.7715
229	286.0213	286.2711	286.5211	286.7712	287.0214	287.2717	287.5221	287.7726	288.0232	288.2739
230	288.5248	288.7757	289.0268	289.2779	289.5292	289.7806	290.0321	290.2837	290.5354	290.7872
231	291.0391	291.2912	291.5433	291.7956	292.0479	292.3004	292.5530	292.8057	293.0585	293.3114
232	293.5644	293.8175	294.0708	294.3241	294.5776	294.8311	295.0848	295.3386	295.5925	295.8465
233	296.1006	296.3548	296.6091	296.8636	297.1181	297.3728	297.6275	297.8824	298.1374	298.3925
234	298.6477	298.9030	299.1584	299.4139	299.6696	299.9253	300.1812	300.4371	300.6932	300.9494
235	301.2057	301.4621	301.7186	301.9752	302.2319	302.4887	302.7457	303.0027	303.2599	303.5172
236	303.7746	304.0321	304.2897	304.5474	304.8052	305.0631	305.3211	305.5793	305.8375	306.0959
237	306.3544	306.6130	306.8717	307.1305	307.3894	307.6484	307.9075	308.1667	308.4261	308.6855
238	308.9451	309.2048	309.4646	309.7244	309.9844	310.2446	310.5048	310.7651	311.0255	311.2861
239	311.5467	311.8075	312.0684	312.3294	312.5904	312.8516	313.1130	313.3744	313.6359	313.8975
240	314.1593	314.4211	314.6831	314.9452	315.2073	315.4696	315.7320	315.9945	316.2572	316.5199

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CHEMICALS FOR BRUSH CONTROL IN CALIFORNIA REFORESTATION

By

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ABSTRACT: This report summarizes findings from experimental trials with selective herbicides applied to forest shrubs and trees in California and adjacent regions. It also recommends formulations and amounts to apply to various species.

Brush forms a major obstacle to reforestation in California. It can deplete soil moisture, provide protective cover for destructive rodents, and impede tree growth. On cleared sites, brush quickly resprouts and reseeds. It competes with newly planted trees and established young growth.

Almost all woody shrub species in the commercial timber zone of California produce large quantities of seeds. Some seeds retain their viability for years and then germinate when exposed to favorable conditions (Quick, 1956, 1959). Many of the more common species sprout from stumps and roots after their aerial parts have been killed (Bruce, 1939; Dunning and Kirk, 1939; Leonard and Harvey, 1956; Roy, 1955; Schubert, 1950, 1955).

Foresters are always seeking more effective methods of controlling brush in planting site preparation and in the release of established trees. Chemicals for brush control have won increasing attention because they show promise in a large number of experiments.

This paper summarizes findings in the literature on the use of chemicals in planting site preparation and reports the results of Station tests of selective herbicides for release of established trees. Although the Station experiments are chiefly small-scale trials, they produced information which may be useful in operational size jobs. Some preliminary recommendations, based on the author's interpretation of these and previously published results, are tabulated as a rough guide to operational decisions.

PLANTING SITE PREPARATION

Competing brush can be killed by mechanical means, such as clearing land with a tractor, or by chemicals used alone or in combination with other measures. If an area is to be burned, the effectiveness of the fire can be increased either by crushing the brush with a tractor or by killing the brush with chemicals. Planned burning will probably not be widely used either with or without chemical pretreatment because of the serious risk associated with prescribed burning in California. Spraying brush before mechanical eradication serves no useful purpose.

After viable brush seeds have germinated, followup chemical treatment may be applied either before or after tree planting. Some evidence indicates that shade from brush benefits the initial establishment of trees (Dahms, 1950; Show, 1924, 1930); however, brush competion is generally harmful after trees are established (Tackle and Roy, 1953). Tarrant (1957, 1958) found that the soil moisture on plots with cleared or dead brush remained above the wilting point in central Oregon, whereas under live shrubs the moisture content had dropped below the wilting point at the 10-14-inch and 20-24-inch depths before the first fall rain in September. Brush should be sprayed before it becomes increasingly resistant to chemical treatment and before it becomes a serious fire hazard when killed.

Experience in killing brush with chemicals for planting site preparation in California has been limited mainly to experimental trials. Most of the tests have been applied selectively to individual plants rather than on an area basis.

Many chemicals have been tested as brush killers in western forest areas (Bruce, 1939; Cox and Ritchie, 1960; Dahms, 1955, 1961; Gratkowski, 1959, 1961; Leonard and Harvey, 1956; Offord, 1949; Offord, Quick, and Moss, 1958; Roy, 1956; Schubert, 1950, 1955). Of all the chemicals tried the herbicides 2,4-D and 2,4,5-T have been the most extensively tested and widely used. The low volatile ether esters of these two herbicides have been generally favored because they have given consistently good results on woody plants and minimized risks of damaging crop plants near treated areas (Dahms, 1955, 1961; Gratkowski, 1959, 1961; Leonard and Harvey, 1956).

In these tests, some brush species were easily killed by low rates of application regardless of when plants were treated. Others showed no appreciable kill under the conditions tested in some areas and good kill under other conditions. Relatively few tests used more than one rate or more than one spray date.

Many researchers have attempted to identify the field conditions that will result in optimum kill of brush, recognizing that stage of plant development, soil and climatic environment, species of plant, and even time of day when sprays are applied would have to be evaluated (Dahms and James, 1955; Gratkowski, 1959; Leonard and Harvey, 1956; Offord, 1949, 1958; Schubert, 1950, 1955). In small trials with Sierra evergreen chinkapin in California, the author obtained best results with early morning treatment with 2,4,5-T. Early morning and late afternoon treatments with 2,4-D gave better kill than mid-day work but were not as effective as the early morning sprays with 2,4,5-T. Where mixed species of brush are concerned, it will always be necessary to make a practical compromise on when and how to treat.

Foliage sprays usually provide the most effective control of brush. On undesirable hardwood trees, however, better kill has been attained by applying the chemicals to cut stumps or in frills. Enough solution should be applied per tree to fill the frill of the completely girdled trunk near the root crown. Roy (1956) found that the effects of the herbicide in frills was delayed, but the vigor of treated trees decreased more the third and fourth years than that of trees which received a basal spray. Bruce (1939) reported a 95 percent kill on live oak stumps treated with a 10 percent aqueous solution of sodium chlorate. With a 1 percent solution of 2,4-D, Schubert (1950) found that madrone proved easier to kill than tanoak. The midsummer treatment was best on madrone and the fall treatment for tanoak.

For hard-to-kill species the addition of a gallon of light summer oil per acre (Dahms, 1961) or about 5 percent by volume of diesel oil (Gratkowski, 1959) has increased the kill in Oregon. Leonard (1961) reported that the addition of some oil to spray mixtures increased the kill. The amount of oil (either kerosene or diesel oil) to be added should normally not exceed 1 percent or 1 gallon per acre for California brush species. Schubert (1955) found that adding wetting agents or emulsifiers did not increase the effectiveness of sprays appreciably.

Gratkowshi (1961) found that a combination treatment of spray-burn-spray gave good results in Oregon. In July, 1955, an 80-acre brushfield composed mainly of greenleaf manzanita and mountain whitethorn ceanothus was sprayed with 2,4-D at a rate of 3 pounds acid plus 1.5 gallons diesel oil per acre. Almost every species resprouted. In late September 1956, the brush was burned. Extensive resprouting occurred again, along with about 10,000 new brush seedlings per acre. A respray in 1958 killed about 90 percent of the new brush. A second respray in 1959 destroyed almost all the remaining brush on the area.

Herbicide treatments suggested for common brush or hardwood species in California are listed in table 1. These suggestions are based on interpretation of results from the studies cited, and readers who wish more detailed information should consult the publications. Because the suggested treatments are interpretations, the data in table 1 may differ from the published results. An asterisk (*) in the table indicates that treatment and expected results are mainly a "best estimate" in this author's opinion.

Nonsprouting species, labeled (N) in table 1, are generally killed with one spray treatment. Many sprouters, labeled (S), may require two or more treatments to obtain satisfactory kill.

The best time to spray has not been determined for all brush species. Where both spring and fall periods have been included, the fall months have usually given the best results. Brush should not be sprayed when the temperature drops below 36°F.

The water miscible, low-volatile ether ester form of the suggested herbicide should be used. Examples include propylene glycol butyl ether ester and butoxy ethanol ester.

Rate refers to pounds of active material. For aerial application, 5 to 10 gallons of solution per acre have given good results. For hand or power sprayers 50 to 150 gallons per acre are needed to get good coverage depending on height and density of the brush. One gallon of light summer oil or diesel oil per acre should be added to get better kill where no conifers are involved. If conifers are present and are to be saved, not more than 1 lb./A of 2,4,5-T should be used; 2,4-D can be substituted for Douglas-fir areas. To kill undesirable hardwood trees, 1 gallon of herbicide (4 pounds acid equivalent) should be used to 10 or 12 gallons of low grade diesel oil or 1 gallon oil plus 10 gallons of water. Enough solution should be applied per tree to fill the frill of the completely girdled trunk near the root crown.

The amount of kill shown in the table indicates the percent top kill (100/) and the percent root kill (/100) based on best kill obtained. Where top or root kill is less than 100 percent, the brush should be re-treated if a heavier kill is needed.

RELEASE OF ESTABLISHED TREES

TESTS AT STANISLAUS

One of the more important uses of selective herbicides in the future may be to release young trees from competing brush. A small-scale test[1] on the Stanislaus Experimental Forest in California indicated that young sugar pines could be safely sprayed with low volatile ester of 2,4-D and 2,4,5-T in spring before the start of growth and in fall after top growth had been completed (table 2). Twenty trees growing in clumps of mountain whitethorn ceanothus were treated with 2,4-D and 2,4,5-T in each of eight months. Each tree-brush clump was drenched with a mist spray at the rate of 200 lb./A of acid in water. Trees sprayed during the growing period were damaged more severely by 2,4-D than by 2,4,5-T. The damage was restricted mainly to the new growth on both terminal and lateral shoots.

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[1] Methods and findings pertaining to these tests will be published elsewhere in greater detail.

In another study, young sugar pines treated with 2,4,5-T in water at dosages of 1/4 to 1 pound acid per acre showed no serious damage, but rates of 2 and 4 pounds acid per acre resulted in higher mortality and reduced growth. Six 1/10-acre plots of sugar pines in dense mountain whitethorn were sprayed on September 24, 1959. Four of the plots had some ponderosa pines and incense-cedars. Most trees were as tall or slightly taller than the brush. None of the incense-cedars was killed. The amount of first-year kill for the pines and mountain whitethorn was:

Herbicide (Rate, lb./A)	Sugar pine	Ponderosa pine	Mountain whitethorn
	- - - - - - - -	- - (Percent)- -	- - - - - - -
1/4	0	0	0
1/2	0	0	25
1	4	--	50
2	15	--	60
4	55	75	80

The average growth of the living trees during the first growing season after treatment was:

2,4,5-T (Rate, lb./A)	Sugar pine	Ponderosa pine	Incense-cedar
	- - - - - - - -	(Inches)- -	- - - - - - -
0	4.3	6.7	3.1
1/4	6.5	9.8	2.4
1/2	3.8	3.1	2.2
1	2.5	--	--
2	-2.2	--	--
4	-4.8	-5.7	-9.1

OTHER STUDIES

Older ponderosa and Jeffrey pines in a manzanita brushfield at Mount Shasta showed damage when treated with 2,4-D and 2,4,5-T during the growing period.[2] They revealed little to no damage when sprayed early in the spring or in September even at a rate of 4 pounds per acre.

In Oregon, ponderosa pines fully exposed to sprays of 2,4-D at rates of 2 pounds or more acid per acre were completely killed or nearly so, but a 1-pound rate caused only slight damage (Dahms, 1955). Dahms (1961) later found that ponderosa pine can tolerate about twice as much 2,4,5-T as 2,4-D and about twice as much of either chemical in water as in an emulsion (1 gallon summer oil per acre). Tolerance of these trees to the two herbicides varied with season. Treatments in July did the most damage to terminal buds, and spraying in late September did the least damage.

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[2] Methods and findings pertaining to the test on manzanita brushfield at Mount Shasta will be published elsewhere in greater detail.

Dahms (1955) has also indicated that Douglas-fir, lodgepole pine, Port-Orford-cedar, western white pine, grand and white firs, and Sitka spruce could be treated at a rate of 1 pound acid per acre of 2,4,5-T without serious damage. The propylene glycol butyl ether esters of 2,4,5-T were reported to cause less damage than butoxy ethanol esters (Krygier, 1961). Gratkowski (1961) found that Douglas-fir was more resistant than sugar and ponderosa pines to 2,4-D and 2,4,5-T. In his study, Douglas-fir was about equally resistant to both chemicals. Since a number of brush or hardwood species commonly associated with Douglas-fir are more susceptible to 2,4-D, this herbicide may be used where Douglas-firs are to be released from competition with tanoak and madrone.

Brushfields of easily killed species which are stocked with suppressed conifers can be treated with low concentrations of 2,4-D and 2,4,5-T to release the trees. For release of conifers the entire brush need not be killed. The herbicides should be applied in spring before tree growth starts or in fall when the trees are dormant. The rates should not exceed 1 pound of acid per acre and 1/2 to 3/4 lb./A may be preferable.

Table 1.--Herbicide treatment for common brush or hardwood species in California

Plant species	Time to treat	Herbicide	Rate lb./A	Kill	Authority[1]
Bearmat (S) *Chamaebatia foliolosa*	Sept.-Nov. March-May	2,4-D or 2,4-D + 2,4,5-T	8	100/80-95	(3, 23)
Big sagebrush (S) *Artemisia tridentata*	April-June	2,4-D	2	100/100	(4, 11, 15)
Bigleaf maple (S) *Acer macrophyllum*	May-June	2,4,5-T	4	100/ ?	(15)
Bitter cherry (S) *Prunus emarginata*	Aug.-Oct. March-April	2,4,5-T or 2,4-D + 2,4,5-T	4	100/90	(2)*
Blueblossom ceanothus (N) Ceanothus thyrsiflorus	Aug.-Oct. March-April	2,4-D or 2,4,5-T	2	100/100	(15)
Bracken fern (S) *Pteridium*	June-July	2,4,5-T	1	100/90	*
California black oak (S) *Quercus kelloggii*	Oct.-April	2,4,5-T or 2,4,5-T + 2,4-D	4	90/50-90	(15)*
Chamise (S) *Adenostoma*	Nov.-June	2,4-D	3	90/80	(2, 14, 15)
Chokecherry (S) *Prunus*	May-June Aug.-Oct.	2,4,5-T	4	100/90	*
Currant (S) *Ribes*	May-June	2,4,5-T	2	100/90-100	(17)

NOTE: See Footnote at end of table.

Table 1.--Continued

Plant species	Time to treat	Herbicide	Rate lb./A	Kill	Authority[1/]
Deerbrush ceanothus (S) *Ceanothus integerrimus*	July-Oct. April-May	2,4,5-T or 2,4-D	2	100/70-90	(12)
Golden chinkapin (S) *Castanopsis chrysophylla*	June-July (April, Sept.-Nov.)	2,4,5-T	4	60/0 ?	(12)* (11)
Gooseberry (S) *Ribes*	May-June	2,4,5-T	2	100/90-100	(17)
Greenleaf manzanita (S) *Arctostaphylos patula*	Sept.-Oct. April-May	2,4-D (Fall) 2,4,5-T (Spring)	2	100/90-100	(23)
Hairy manzanita (N) *Arctostaphylos columbiana*	June-July	2,4-D or 2,4,5-T	1-2	100/100	(12)
Littleleaf ceanothus (N) *Ceanothus parvifolius*	April-Nov.	2,4,5-T	1	100/100	(23)
Madrone (S) *Arbutus*	June-July	2,4-D or 2,4-D + 2,4,5-T	4	100/28	(22)
Mariposa manzanita (N) *Arctostaphylos mariposa*	May-June	2,4-D	2	100/100(?)	(14)
Mountain whitethorn ceanothus (S) *Ceanothus cordulatus*	April-May Sept.-Nov.	2,4,5-T	2	Old plants 100/20 Young sprouts 100/80	(23)

NOTE: See footnote at end of table.

Table 1.--Continued

Plant species	Time to treat	Herbicide	Rate lb./A	Kill	Authority1/
Parry manzanita (N) *Arctostophylos parryana*	April-June	2,4-D or 2,4,5-T	2	100/100	(*5*, *7*)
Poison-oak (S) *Toxicodendron quercifolium*	May-June	2,4-D + 2,4,5-T	2	100/90	(*15*)
Rabbitbrush (S) *Chrysothamnus*	May-June	2,4-D	2	100/100(?)	(*11*)
Salal (S) *Gaultheria shallon*	May-June Sept.-Oct.	2,4-D + 2,4,5-T	2	?	*
Scotch broom (S) *Cytisus scoparius*	Aug.-Oct.	2,4-D	2	100/90(?)	(*15*)
Serviceberry (S) *Amelanchier*	July-Sept.	2,4,5-T	2	100/80	*
Sierra evergreen chinkapin (S) *Castanopsis chrysophylla*	Sept.-Nov.	2,4,5-T	8	Old 100/20 Young 100/60	(*5*,*23*)
Snowbrush ceanothus (S) *Ceanothus velutinus*	April-June Aug.-Oct.	2,4,5-T or 2,4-D	2	100/50	(*7*, *12*)
Squawcarpet ceanothus (S) *Ceanothus prostratus*	Sept.-Nov. March-May	2,4,5-T 2,4-D + 2,4,5-T	2	100/90	(*15*)

NOTE: See footnote at end of table.

Table 1.--Continued

Plant species	Time to treat	Herbicide	Rate lb./A	Kill	Authority[1]
Tanoak (S) *Lithocarpus densiflorus*	Sept.-Nov.	2,4-D, 2,4,5-T or 2,4-D + 2,4,5-T	4	Trees 65/30 Sprouts 100/100	(21, 22)
Whiteleaf manzanita (N) *Arctostaphylos viscida*	Sept.-Nov. April-May	2,4-D	2	100/100	*
Willow (S) *Salix*	July-Sept.	2,4-D	2	100/80(?)	(15)

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[1] Numbers refer to Literature Cited at end of report.

Table 2.--Effect of 2,4-D and 2,4,5-T on young sugar pines growing in clumps of mountain whitethorn, by month of application

Year and month	Average damage rating[1/]			
	Trees		Brush	
	2,4-D	2,4,5-T	2,4-D	2,4,5-T
1958				
July	2.2	2.4	1.4	3.6
August	1.6	0.2	2.0	3.2
September	0.2	0.0	1.8	2.4
October	0.0	0.2	0.4	3.2
November	2.6	0.0	2.0	1.2
1959				
April	0.0	0.0	0.0	3.0
May	2.5	0.4	3.2	4.0
June	2.6	1.6	3.0	3.2

[1/] 0 = none; 1 = slight; 2 = moderate; 3 = severe; 4 = killed.

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EXPERIMENTAL DESIGNS FOR SIMPLE PLANTING AND OTHER REFORESTATION EXPERIMENTS

Russell K. LeBarron

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EXPERIMENTAL DESIGNS FOR SIMPLE PLANTING AND OTHER REFORESTATION EXPERIMENTS[1]

By

Russell K. LeBarron,
Research Forester

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Miscellaneous Paper No. 74 1962

U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
Berkeley, California

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[1] Prepared at request of the California State Forester's Advisory Committee on Reforestation.

EXPERIMENTAL DESIGNS FOR SIMPLE PLANTING AND OTHER REFORESTATION EXPERIMENTS

By
Russell K. LeBarron,
Research Forester

Practicing foresters frequently find situations in which either necessity or natural curiosity impels them to experiment. This desire may be stimulated by dissatisfaction with an accepted practice and an idea on how to do it better. Or it may be caused by uncertainty about how to do a job to get acceptable results. Practically always the obvious step is to try one or more methods to see how well they accomplish the desired result.

This report describes some experimental designs that field foresters need when they try new or different methods of artificial reforestation. These suggestions are based on many years of experience and observation. They point out the essential requirements of experimental design that will permit the drawing of reliable conclusions, and some pitfalls which must be avoided. One section of this report shows five sample designs that can be modified or adapted to a considerable variety of problems. The last section explains some principles of data analysis.

PRINCIPLES OF EXPERIMENTAL DESIGN

KNOWLEDGE OF THE SUBJECT FIELD

Anyone who undertakes an experiment without first making a reasonably thorough search for information runs a good chance of needlessly studying problems which have already been adequately investigated. Searches for information can be made in libraries of forestry and related arts and sciences, such as horticulture and botany. Recognized authorities also can be consulted. Many planting experiments have been duplicated unnecessarily.

DETERMINATION OF THE PROBLEM

Efficient experiments demand a clearly defined objective. The object must be stated in a form that will give a reasonably decisive answer with the facilities and skills that are available. Poorly defined experiments can be compared to a novice rearranging the wires in a radio. The result may be better performance by the radio, but the odds are very much against it. Rarely should experiments be undertaken for the vague purpose of "to see what will happen."

SYMMETRY IN DESIGN

For simple, straight-forward results, all of the elements in a study should be balanced. For example, if 50 trees are given a treatment such as shading, an equal number of identical trees (same seed lot, same age, same nursery, etc.) should be left unshaded or given a different degree of shading as a check or comparison. Another example: In a more complex experiment involving two species and two degrees of shading, equal numbers of the two species must be used, and half of each of these must be subject to the two degrees of shading as shown below.

Species	Trees (number)	Treatments (number)	
		25 percent shade	50 percent shade
Ponderosa pine	50	25	25
Jeffrey pine	50	25	25

CONFOUNDING

Confounding in experimental design means having two conditions affecting a result in such a way that the individual effect of each cannot be separated. For example:

Species	Date of Planting	Survival after 1 year (percent)
Ponderosa pine	November 1960	60
Jeffrey pine	April 1961	80

Which caused the higher survival--the greater hardiness of Jeffrey pine or the time of planting? This example may be so obvious that it appears to insult the reader's intelligence, but it is one of the greatest pitfalls for the uninitiated in experimental design. Confounding often occurs much more subtly than in the above example. The possibilities for confounding are almost limitless--source of seed, site, aspect, planters, planting methods, stock ages or handling, and protective measures, including screening seed spots. Furthermore, accidents of nature, such as deer browsing or insect damage, can confound an experiment.

REPLICATION

To replicate means to make more than one installation of an experiment. Six replications in an experiment includes six counterparts. The simplest explanation of the reason to replicate is to increase the opportunity for the treatments to give consistent results. If we observe the same reaction from several or many independent repetitions of the same test, we gain greater confidence that the result is actually a consequence of the treatment instead of an accidental coincidence. Obviously, the more replications, the higher the degree of confidence. From the results of a properly designed experiment, the degree of statistical confidence in results can be calculated. For example, you can tell whether such a situation might be expected frequently or as infrequently as once in 20, the 95 percent probability level. Replication is an essential requirement for efficient experimentation.

The actual number of replications to use in a test is more difficult to determine. It depends upon the inherent variability in the subject material, accidents, the margin of difference in response between the various treatments in an experiment, and the degree of confidence in results that is desired. For planting tests, 3 to 6 replications will usually be enough to estimate the statistical significance and to judge the practical use of differences between treatments such as Jeffrey pine vs. ponderosa pine, 1-0 vs. 2-0 stock, and shaded vs. unshaded. One complete installation (or replication) of all treatments is called a block.

RANDOMIZATION

To randomize in experimental design means to assign the treatments to different plots within a block by a method which allows an equal chance for each treatment to fall on any given plot. Randomization eliminates both mechanical arrangement of treatments and personal bias in assignment. Anyone who wishes to understand the reasons should consult publications on statistical analyses. Randomization is an essential prerequisite both to good experimental design and statistical analysis of results. Randomization can be done by drawing numbers from a hat to determine the order of arrangement, or by other equally simple systems. The plots in one block may be arranged by some systematic plan if it will be convenient or desirable for demonstration.

SIMPLICITY OF DESIGN

The simpler and the fewer the comparisons in an experiment, the easier a study can be designed, and the better the chances are to obtain decisive results. More than three variables in a single experiment probably should be viewed with suspicion. Consider the following test:

Factor	Number of variables
Species	3 (J.P., P.P., S.P.)
Planting method	2 (hand vs. machine)
Site preparation	2 (machine clearing vs. uncleared)

Sample size	25 (trees per plot)
Replications	4 (blocks)

Total number of trees = 3 x 2 x 2 x 25 x 4 = 1,200

Thus it is seen that this relatively modest, simple experiment grows into a rather big job to lay out, install, protect, and measure. If another variable such as two age-classes had been added, the number of trees would have jumped to 2,400. By reducing the number of replications to 3, however, the total could be cut to 1,800 trees.

SAMPLE SIZE

Because seeds and seedlings are inherently variable organisms, we generally need to base estimates for each independent sample on the average or sum of several organisms. Large samples, say 100 seed spots or planted trees per plot, will give more consistent averages or sums in such terms as number of germinates, occurrence of injury, number of survivors, and height growth, than will samples of only 5 or 10 trees. On the other hand, if smaller samples are used, more plot replications can be made with the same amount of effort. The trick is to strike a happy medium. Naturally the ideal balance differs for every problem. Specific suggestions are made in the section at the end which includes basic sample designs.

Large plots (100 or more trees per plot) often are more impressive for demonstration purposes and in certain circumstances they may be imperative, but they add materially to costs and usually add little to statistical validity. Sometimes large plots lessen the reliability of the results. A general rule might be: "When in doubt use smaller samples in more replications. If you have 200 seeds or plants, a better design is to plant 50 in each of four replications than to plant 100 in each of two replications."

ARRANGEMENT OF PLOTS

Within a single block or replication of an experiment, the plots should be as comparable as possible in all respects. Comparability should include physical factors of site, time, methods of planting, and condition of the test material. For instance, the soil, slope, aspect, and vegetation should be the same and the trees should all be planted the same day by the same person. If more than one man is required to get the job done, each worker should plant equal proportions of the trees in each plot.

If plots are long and narrow, such as one row of 25 trees, they should sample the full range of any visible gradient, such as slope or change in depth of soil. For example, in plots on a slope, rows should run up-and-down hill. The purpose is to insure that each plot samples as nearly as possible the full range of variation within the block. Plots should be placed as close together as possible although allowance must be made for isolation strips if the treatments, such as applying fertilizers, might affect their neighbors.

ARRANGEMENT OF BLOCKS

Unlike plots, the separate blocks need neither be alike nor close together. Usually there is some advantage in deliberately selecting blocks that are some distance apart and slightly different. This has the effect of testing the experimental treatments over a somewhat greater range of conditions (different soils, different slopes, different planters, etc.).

Blocks must not be so different in character that interactions are likely to occur between the experimental treatments and some condition that affects the experiment, for example, species and soil type.

SPACING OF TREES

For efficiency in layout of experiments, the spacing of trees or seed spots should be considered in relation to the objectives. For example, if the objective is to measure first year survival, the trees can be spaced only 2 or 3 feet apart rather than 8 or 10 feet as in standard planting. By placing the trees close together, less space is required, variability in habitat can be reduced, and measurement and protection are made easier. On the other hand, if growth for 5 or 10 years is desired, closely spaced trees would compete among themselves more than in typical standard plantings, so standard spacing should be used.

Border effects also must be considered. For example, if a plot of fast growing hybrids is planted adjacent to a plot of slower growing trees, the trees along the adjacent boundary will react differently than in the interior portions of the plots. The common method to prevent border effect is to plant one or two extra rows outside of the part of the plot that is to be measured.

FIVE BASIC DESIGNS FOR REFORESTATION EXPERIMENTS

1. Field test of initial survival in which plots can be closely spaced (randomized block design).

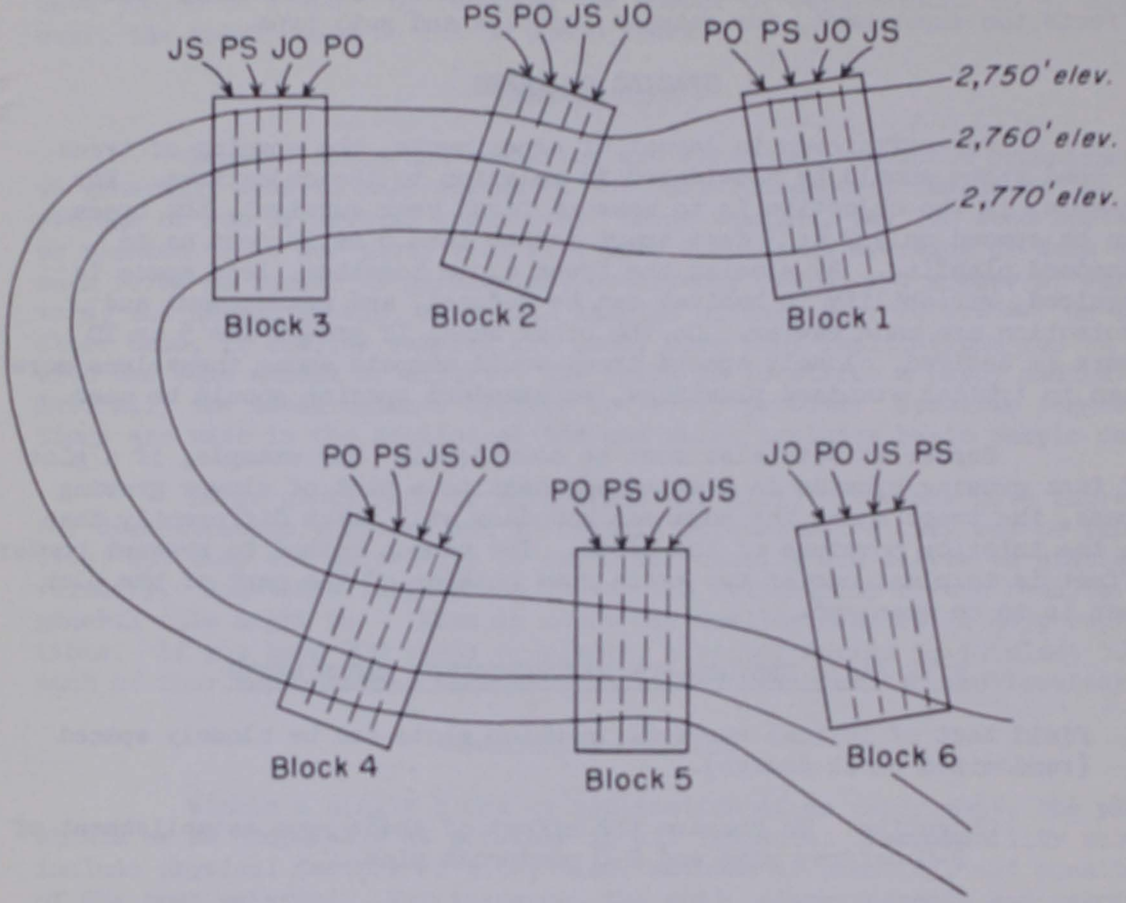
Objective: To compare the effect of shade upon establishment of 2-0 Jeffrey pine and 2-0 ponderosa pine.

Desired statistic: Survival after two growing seasons in field.

Plan: One 25-tree row of each treatment combination is a plot. Six replications. Space trees 3 feet within rows, 6 feet between rows.

Treatment code: J, Jeffrey pine; P, ponderosa pine; S, shade; 0, no shade.

Replication or block numbers: B-1, B-2, B-3, B-4, B-5, B-6.



JS PS JO PO
PS PO JS JO
PO PS JO JS
2,750' elev.
2,760' elev.
2,770' elev.
Block 3
Block 2
Block 1
PO PS JS JO
PO PS JO JS
JO PO JS PS
Block 4
Block 5
Block 6

2. Field test of survival and early growth in which plots cannot all be closely spaced, such as when plantings on burns and large tractor-cleared areas are compared with those in natural vegetational cover (split plot design).

   Objective: To compare survival and early growth of three age-classes of ponderosa pine (1-0, 2-0, and 2-1) on burned and unburned areas.

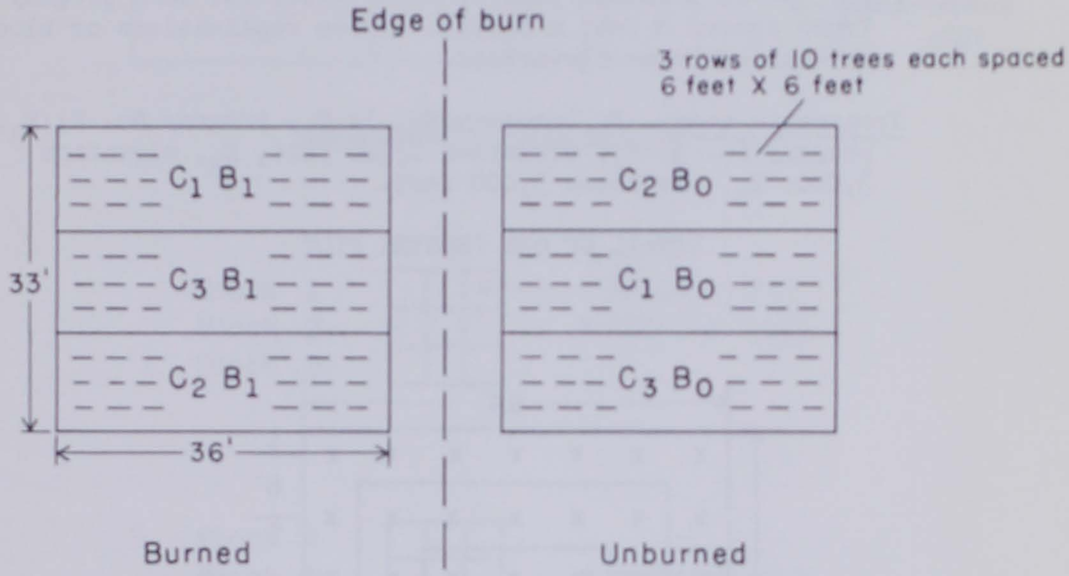
   Note: Since the plots must be placed inside and outside of the burn, the assignment of treatment areas is not completely independent. A split plot arrangement, which requires a slightly different type of statistical analysis, offers a satisfactory solution.

   Desired statistics: Survival and average height after five growing seasons.

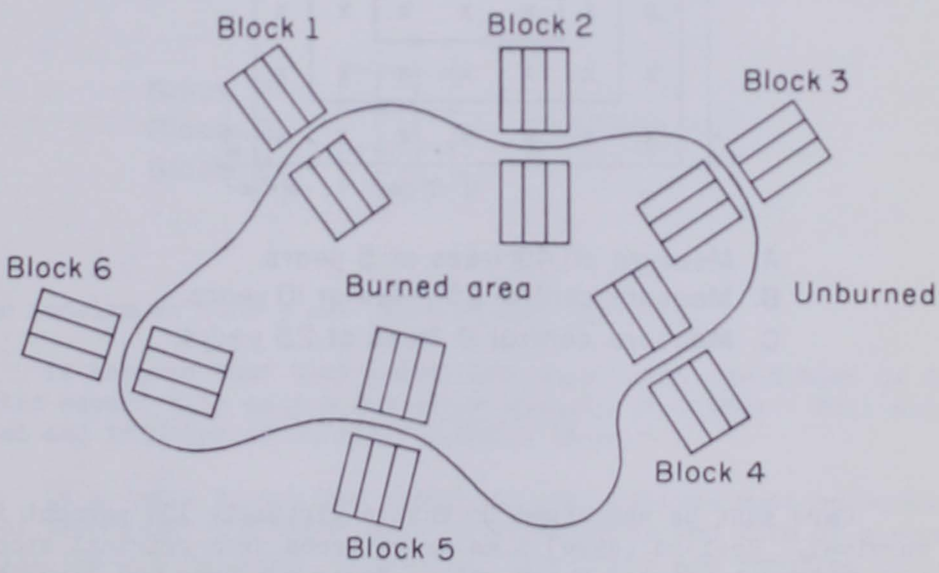
Plan: Three adjacent rows of 10 trees each for every treatment combination. Six replications. Space trees 6 feet in rows and 6 feet between rows.

Treatment code: C_1, 1-0 stock; C_2, 2-0 stock; C_3, 2-1 stock; B_1, burned area; B_o, unburned.

DETAILED PLAN OF ONE REPLICATION (BLOCK)


Edge of burn
3 rows of 10 trees each spaced 6 feet X 6 feet
C_1 B_1
C_3 B_1
C_2 B_1
33'
36'
C_2 B_0
C_1 B_0
C_3 B_0
Burned
Unburned

GENERAL PLAN FOR SIX REPLICATIONS


Block 1
Block 2
Block 3
Block 6
Burned area
Unburned
Block 4
Block 5

3. Field test of long-time performance (randomized block design).

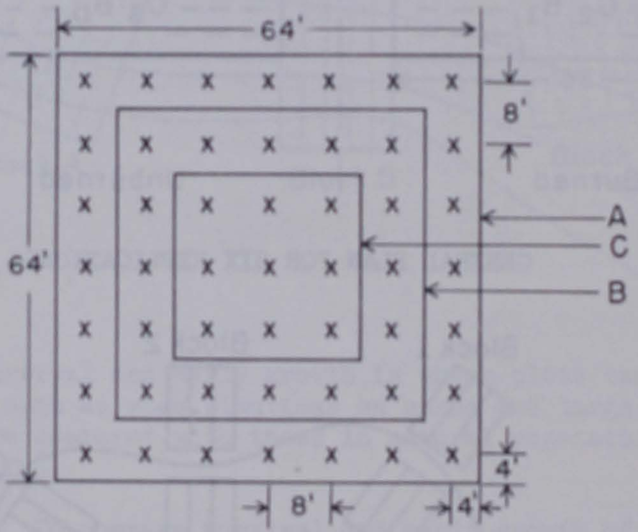
Objective: To determine the performance (growth, and adaptability to adverse weather conditions) of three different progenies planted at high, medium, and low elevations.

Desired statistics: Survival at 5, 10, and 25 years; height at 5, 10, and 25 years; basal area per acre at 25 years.

Plan: Seven parallel rows of seven trees for each progeny plot. Trees spaced 8 feet x 8 feet. Three replications or blocks at each of three elevations.

Treatments code: P_1, progeny No. 1; P_2, progeny No. 2; P_3, progeny No. 3; E_1, elevation 1,000 feet, E_3, elevation 3,000; E_5, elevation 5,000 feet.

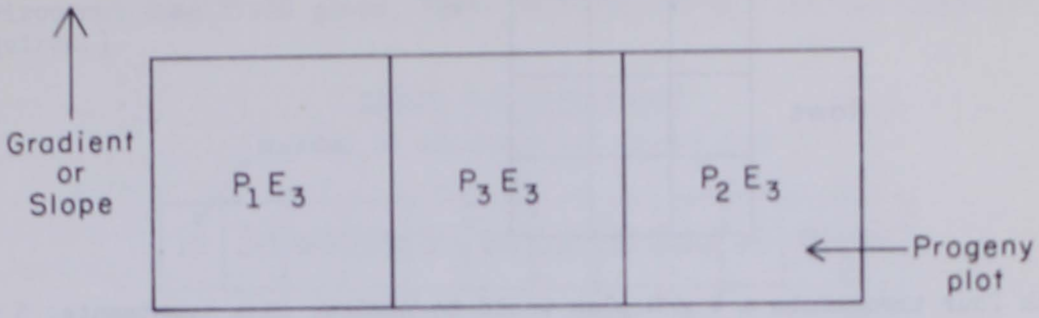
DETAIL OF ONE PROGENY PLOT



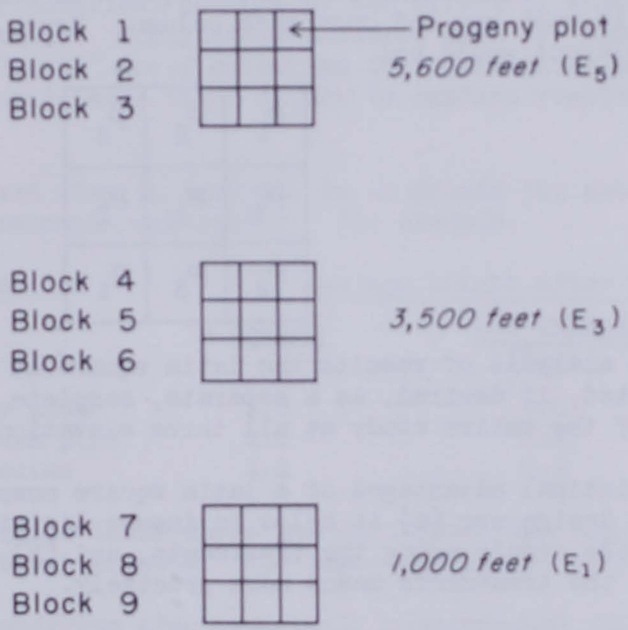
A. Measure all 49 trees at 5 years.
B. Measure central 25 trees at 10 years.
C. Measure central 9 trees at 25 years.

Care must be exercised to insure virtually 100 percent first-year survival. Heel-in (save) some extra trees from original stock and promptly replace any trees which fail. Fence out deer and livestock.

ARRANGEMENT OF ONE BLOCK


Gradient
or
Slope
P1 E3
P3 E3
P2 E3
Progeny
plot

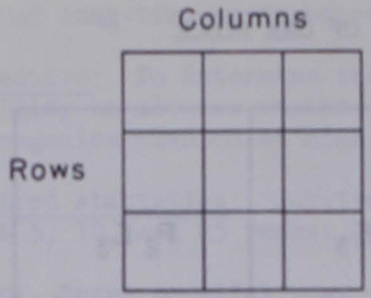
ARRANGEMENT OF ALL BLOCKS


Block 1
Block 2
Block 3
Progeny plot
5,600 feet (E5)
Block 4
Block 5
Block 6
3,500 feet (E3)
Block 7
Block 8
Block 9
1,000 feet (E1)

4. Same problem as item 3 but latin square design.

It happens that this particular experiment could also be designed as a latin square with only a few minor changes in layout. This will be explained and illustrated on the following page.

In a latin square the number of replications must be equal to the number of treatments and these must be arranged in the form of a square. Thus, with three treatments, a total of nine plots are required in the form of three columns and three rows:



With four treatments a 4 x 4 plan would be needed; five treatments, 5 x 5, and so forth. Obviously, if more than six or seven treatments are involved, the latin square design would become rather cumbersome. Ordinarily, it would not be used in tree planting experiments if the number of treatments exceeded seven.

The second requirement of a latin square is that each treatment must occur once in each row and once each column. Hence, at any one elevational zone the layout would be:

P_1	P_2	P_3
P_3	P_1	P_2
P_2	P_3	P_1

In the analysis of results the latin square at each elevational zone can be treated, if desired, as a separate, complete experiment, as well as a part of the entire study at all three elevations.

The principal advantages of a latin square compared to a randomized block design are (a) it helps to insure distribution of any habitat differences evenly among the treatments, and (b) it measures variance between the treatments means more precisely.

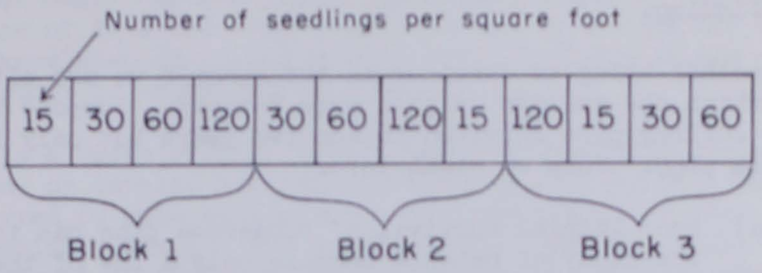
5. Nursery experiment (randomized block design).

Objective: To determine size of 1-0 seedlings grown at densities of 15, 30, 60, and 120 trees per square foot.

Desired statistics: Individual stem diameters at ground level and total oven dry weights of tops and roots at time of lifting (November 10).

Plan: Four feet x four feet sections of seedbed will be the areas in which seedlings will be grown evenly spaced at the specified densities. The 50 seedlings nearest to the center of each 4-foot square will constitute the sample. Three replications used. (Note: Because nursery seedbeds are less variable in environment than field plots, fewer replications and smaller plots are required.)

LAYOUT FOR EXPERIMENT



ANALYSIS AND INTERPRETATION OF DATA

The primary objective of designed experiments should be to get a quantitative or numerical measure of the effect of some experimental variable or treatment. Qualitative measures such as "slightly injured," "unthrifty," or "small" are of limited use for statistical analysis although they may have considerable value either to explain results or for practical application.

The first step in analysis is to obtain the average value of each treatment and treatment combination. For example:

Species	Average height after 2 years		
	Shaded	Not shaded	All treatments
	- - - - - - - -	(Feet)	- - - - - - - -
Jeffrey pine	1.0	0.6	0.8
Ponderosa pine	1.2	1.2	1.2
All species	1.1	0.9	1.0

This simple table shows the occurrence and magnitude of differences among treatment effects. The important points are:

(a) Ponderosa pine apparently outperformed Jeffrey pine.
(b) Jeffrey pine apparently benefited from shading, but ponderosa pine did not.

The next thing is to look back at the data in the several replications to see whether the differences are uniformly consistent. For example, if ponderosa consistently outperformed Jeffrey pine and if Jeffrey pine consistently benefited from shade, the differences are probably dependable.

The next step is to look back into the field records to see if any external cause might explain the poor showing of Jeffrey pine, for example, was it more heavily browsed by deer? With regard to absence of shading effect on ponderosa pine, were the shades possibly knocked down by cows? Too small? At this stage, the analyst must be extremely critical and cautious to be convinced that observed differences in response were or were not influenced by external conditions. By means of good field records and careful analysis, the experiment might have accidentally revealed that deer prefer Jeffrey pine to ponderosa pine. This could be a valid although unexpected finding.

Another thing to consider in the example we are citing is the bases from which the average heights were derived. Suppose that 90 percent of the Jeffrey pine survived to age two years but only 10 percent of the ponderosa pine. Then we might infer:

(a) Poor initial survival of ponderosa pine has invalidated the study of heights because only a few of the most vigorous trees survived and thus resulted in a distorted picture of the height growth of this species.

(b) Getting good initial survival of ponderosa pine is a more important problem than the effect of shade, or at least, it must be solved before the effect of shade can be evaluated.

After completing this critical review of cause and effect relations within the experiment, the analyst should consider the practical consequences. For example, how important is an average gain in height of 0.4 foot on Jeffrey pine? Does it appear to be worth the cost of shading or would a better plan be to save the cost of shading to get more acres planted with the available funds? Is the faster initial start made by ponderosa pine important enough to warrant using this species to the exclusion of Jeffrey pine on the kind of sites where the tests were made? If the answer to either or both of the last two questions is "Yes," then a statistical test may be needed to determine if the differences are statistically significant.

STATISTICAL SIGNIFICANCE

Tests of statistical significance neither add anything to the results nor change the results. Nor do statistical significance tests guarantee that the same experiment, if repeated, will yield identical results. These tests simply indicate what are the odds that the observed differences were not due to chance or, in somewhat stricter statistical language, "The statement that the treatment means are different has certain odds of being correct on the average," according to such tests. For example, when an analysis of variance indicates that a difference due to treatments is "significant at the 5 percent level," this means that the odds are 19 to 1 that the observed difference resulted from the treatment rather than from accident or chance.

If you like odds of 2:1, you are entitled to say the results are "significant" provided that you specify that this is the level of confidence that you accepted. Or if you are more cautious or strict in requirements, you may not be satisfied that the results are significant unless the odds are 499:1 or even 9,999:1. The most commonly used level in forestry and similar sciences is 19:1, but it must be remembered that this is wholly a matter of judgment rather than a ratio which has some special mathematical virtue. If human lives were at stake we would insist upon far longer odds. Methods exist by which "judgment" can be removed from the choice of level of confidence, but the processes are laborious, presume much knowledge about the area of work, and are seldom used except for very important or expensive experiments.

It is a waste of time to run tests of significance on data that are confounded, or invalid because of external influences. Also, no useful purpose is served to make such tests if differences are either exceedingly large or exceedingly small. For instance, in a well designed and well executed experiment if the survival which results from one treatment is 5 percent and from another is 95 percent, you would know immediately that the difference was real, and you should not hesitate to apply the findings in your program of work. And, on the other hand, if treatment "A" resulted in 75 percent survival and treatment "B," 76 percent, you would not care if the difference was statistically significant, because you know that dozens of uncontrolled factors can cause planting survival to vary by greater amounts. Tests of significance are helpful only when differences in results are big enough to be possibly important but not so large as to be obviously significant.

No attempt will be made here to describe the steps in making statistical tests for several reasons:

(a) Calculation of statistical tests requires considerable training. Applications by unassisted novices probably would lead to errors and cause wrong interpretations of the experimental results.

(b) Many data require special manipulation (such as transformation into cosines or logarithms) that is impossible to explain briefly.

(c) Many kinds of statistical procedures are available and no one method is universally applicable.

Experimenters who feel the need to determine confidence limits but lack the knowledge should present their problems to mathematics teachers and scientists experienced in biometrics for assistance in getting solutions.

LeBarron, Russell K.
1962. Experimental designs for simple planting and other reforestation experiments. U.S. Forest Serv. Pacific SW Forest and Range Expt. Sta. Misc. Paper 74. 13 pp., illus.

Some do's and don't's for use by practicing foresters who wish to make simple experiments are summarized. Five examples of experimental designs that can be adapted to a wide variety of problems are illustrated with sketches. Some principles of statistical analysis are explained, but procedures for computing confidence limits are not.

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FOREST FIRE RESEARCH in CALIFORNIA, an annotated bibliography, 1923-1961

Carl C. Wilson & Jerry R. Nilsson

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FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

FOREWORD

This publication is in effect a summary of U. S. Forest Service research on fire problems in California through 1961. It lists both published work and unpublished reports on file at the Pacific Southwest Forest and Range Experiment Station.

The Station, called the California Forest and Range Experiment Station until 1959, was established in 1926. Before that time forest fire studies were conducted by the Forest Service's California Region Office of Research, San Francisco. Reports published before the establishment of the Experiment Station are included here to make this list a more useful compilation of research activities.

FOREST FIRE RESEARCH IN CALIFORNIA,

AN ANNOTATED BIBLIOGRAPHY, 1923-1961

By

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Miscellaneous Paper No. 75 1962

U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE

PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION

Berkeley, California

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PUBLISHED WORK

ABELL, C. A.

(1) 1940. Fires on the National Forests of southern California with respect to final areas and distance traveled by the suppression crew on foot. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 9 pp., illus.

Tabulates fires to show the degree to which fire occurrence is associated with roads.

(2) 1940. Rates of initial spread of free-burning fires on the National Forests of California. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Res. Note 24, 26 pp., illus.

Calculates the rate of initial spread from data contained in individual fire reports (Form 929) for fires on the National Forests in California from 1925 to 1937. Rates of spread were tabulated for each inflammability zone or each forest. Curves for each zone show the percentage of fires that burned at different initial rates of spread.

ARMENT, C.

(3) 1950. Wild fire damage and cost far-reaching. Damage of natural resources may be permanent loss of community values. Calif. Agr. 4(9):9-10.

Describes the short, immediate, and long term damages caused by fire. Explains the advantages and uses of the fire damage appraisal tables completed for the Angeles, Cleveland, Los Padres, and San Bernardino National Forests.

ARNOLD, R. KEITH.

(4) 1954. Operation firestop. Soc. Amer. Foresters Proc. 1954: 173-174.

Presents preliminary results of a 1-year cooperative fire research program in California called Operation Firestop. Concludes that further large-scale research is needed to test and develop new ideas and methods to combat mass fires.

(5) 1955. Operation firestop. U.S. Forest Serv. Fire Control Notes 16(2):1-5.

The same as item (4).

ARNOLD, R. KEITH, AND BUCK, CHARLES C.

(6) 1952. East Bay hills grass-fuel fire spread index. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 7 pp., illus.

Shows by means of indexes the relative rates at which fire will spread under combinations of temperature, relative humidity, and wind velocity.

ARNOLD, R. KEITH, AND BUCK, CHARLES C.
(7) 1954. Blow-up fires--silviculture or weather problems? Jour. Forestry 52(6):408-411, illus.

Analyzes for ignition and burning pattern, atmospheric conditions, topographic locations, and surface conditions fires which defy fire fighting because of their intensity or speed.

ARNOLD, R. KEITH, BYRAM, G. M., FONS, W. L., and SAUER, F. M.
(8) 1952. Thermal conductivity of some common forest fuels. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 13 pp.

Reports on conductivity measurements of dry leaves and decayed wood (punk) made by a thin plate uni-directional heat flow calibration stand. Results of these measurements are compatible with a linear relationship between thermal conductivity and specific gravity, established by MacLeon, and indicate that conductivities of most common forest fuels may be determined from their specific gravities.

(9) 1952. Thermal properties of forest fuels. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 34 pp.

Describes the influences of fuel moisture, specific heat capacity, net heat, heat of decomposition, thermal conductivity, dimension, structure, and thermal absorptivity on ignition and initial combustion rather than on subsequent fire behavior.

BLANCHARD, ROBERT K.
(10) 1947. Killing brush with 2,4-D. U.S. Forest Serv. Fire Control Notes 8(2 & 3):13-17, illus.

This first study of 2,4-D as a brush killer for use throughout California provides recommendations for future experiments.

BROIDO, A.
(11) 1960. Mass fires following nuclear attack. Bul. Atomic Scientists 16(10):409-413.

Attempts a realistic appraisal of the fire effects of nuclear attacks. Reviews the process of fire ignition by thermonuclear detonation and the characteristics of fire spread from the original points of ignition. Suggests certain fire control measures for minimizing the overall effects.

(12) 1961. Effect of fire-extinguishing agents on combustion of sucrose. Science 133(3465):1701-1702, illus.

Although sucrose and cellulose are both carbohydrates of basically similar composition, the very materials which are the most effective in preventing flaming combustion of cellulose are also effective in causing sugar cubes to support flame.

BROIDO, A., and McMASTERS, A. W.

(13) 1959. The influence of a fire-induced convection column on radiological fallout patterns. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Tech. Paper 32, 44 pp., illus.

Results of laboratory experiments with fallout simulant suggest that large-scale fires can produce effects which could markedly alter civil defense planning.

(14) 1960. Effects of mass fires on personnel in shelters. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Tech. Paper 50, 84 pp., illus.

Describes studies of temperatures and gases in simulated shelter air intake vents resulting from fires varying in size from a single school room to several acres of stacked fuel. Results show that extreme concentrations of carbon monoxide and temperatures exceeding 2,000°F. might be expected in large fires, along with depletion of the oxygen supply and high concentrations of carbon dioxide. Smoldering rubble was found to maintain higher temperatures and toxic gas concentrations for longer periods than the fire itself. Placing a vent just outside a residence may be of little value since high concentrations of toxic gases will sometimes be found in these locations.

(15) 1961. Fire exposure of people in shelters. Natl. Fire Protect. Assn. 55(2):129-140, illus.

Summarizes tests and findings described in item (12).

BROIDO, A., McMASTERS, A. W., and WILSON, C. C.

(16) 1961. Forest fire research helps develop shelter criteria. Proc. Environmental Engin. in Protective Shelters, Nat. Acad. Sci./Nat. Res. Council 1960:275-295.

Presents results of the early phases of the "shelter" study sponsored by the Office of Civil and Defense Mobilization, Washington, D. C.

BROIDO, A., and MARTIN, S. B.

(17) 1961. Effect of potassium bicarbonate on the ignition of cellulose by thermal radiation. U.S. Nav. Radiological Defense Lab. TR-536, 20 pp., illus.

Reports on a study showing that $KHCO_3$ treatment of alpha-cellulose papers before exposure to thermal radiation reduces their sensitivity to transient flaming and that sustained flaming may be completely prevented without adding more than 1.5 percent by weight. But $KHCO_3$ treatment greatly increases the sensitivity of cellulose to glowing ignition, apparently by increasing the rate and degree of pyrolysis of such combustible gases as H_2, CH_4, C_2H_4, and C_2H_6 at the expense of high molecular weight, tarry materials.

BROWN, A. A.

(18) 1935. Improving forest fire detection in California. Jour. Forestry 33(11):923-931, illus.

Describes development of a rating system based on seen-area maps and fire-occurrence data to determine important lookout points.

(19) 1936. Planning fire lookouts in California. Amer. Forests 42(5):214-215, illus.

Describes the processes involved in selecting the best possible positions for forest fire lookouts.

(20) 1936. Receding string reels for dispatcher maps. U.S. Forest Serv. Fire Control Notes 1:41-42, illus.

Describes how to make and use a string reel for dispatcher maps.

(21) 1936. Vertical angle finder. U.S. Forest Serv. Fire Control Notes 1:39-40, illus.

Describes how to make and use a vertical angle finder for fire finders.

(22) 1937. Design of forest transportation plans to meet the fire control problem in northern California. Jour. Forestry 35(5):490-495.

Reports the need for and outlines the design of specific and well balanced plans for road development in the northern California National Forests.

(23) 1937. Design of transportation plans to meet the fire control problem in southern California. Jour. Forestry 35(6): 563-570.

Describes the development of a master road plan for fire control to provide acceptable speed of first attack and to facilitate effective fire-suppression strategy.

(24) 1937. Fire control progress in California National Forests. Timberman 38(6):18, 20, 22, illus.

Describes the improvement of detection, communication, and transportation systems in each National Forest.

BRUCE, H. D.

(25) 1939. Chemical killing of sprouting stumps. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Res. Note 23, 4 pp, illus.

Extensive tests of herbicidal chemicals showed sodium chlorate as the most reliable and effective in killing sprouting stumps.

BRUCE, H. D.

(26) 1939. The role of chemicals in firebreak maintenance. Utah Juniper 10:12-19, illus.

Describes the use of sodium chlorate and white arsenic to clear firebreaks of sprouting stumps.

(27) 1941. Theoretical analysis of smoke-column visibility. Jour. Agr. Res. 62(3):161-176, illus.

Explains the factors affecting smoke visibility and the contrast ratio between smoke and other visual elements.

(28) 1944. Observations on the visibility of a small smoke. Jour. Forestry 42(6):426-434, illus.

Smokes were observed against various backgrounds. Differences in maximum visibility are shown for each of the three backgrounds: timber, dry grass, and the mottled brush common on southern California watersheds.

BRUCE, H. D., PONG, W. Y., and FONS, W. L.

(29) 1961. The effect of density and thermal diffusivity of wood on the rate of burning wood cribs. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Tech. Paper 63, 14 pp., illus.

Reports experimental data for free-burning fires in cribs of five species of wood, each of several density classes. Results indicate that the rate of fire spread decreased with increasing density. Differences were observed in the rate of spread for different species of wood having the same density. Linear relations were observed when the rate of spread data was plotted against the thermal diffusivity values of the wood. Differences due to species were reduced in these graphs when known values for the specific heat were used in calculating the diffusivity.

BUCK, CHARLES C.

(30) 1938. Factors influencing the discovery of forest fires by lookout observers. Jour. Agr. Res. 56(4):259-266, illus.

Reports on data obtained from tests of fire-discovery time under varying conditions. Shows the interrelation of distance, rate of spread, and position of the sun.

(31) 1950. Fire behavior in relation to factors of environment. Univ. Calif., Davis, Short Course on Range Improvements Proc. 1950:66-71.

Explains the factors affecting fire that are pertinent to the problem of prescribed burning: character, moisture content, and temperature of fuel; velocity of wind; and direction and character of topography.

BUCK, CHARLES C.
(32) 1951. Inflammability of chaparral depends on how it grows. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Misc. Paper 2, 2 pp.

Chaparral changes flammability as its age and the local climate change. When drought conditions prevail dead material on the surface and conflagration potential both increase because the deteriorated cover causes more drying near the surface.

BUCK, CHARLES C., and ABELL, C. A.
(33) 1942. Recommendations of the California Forest and Range Experiment Station for emergency fire protection in the East Bay Hills area. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 10 pp., illus.

Describes the protection of critical forest, grass, and brush-covered lands that would constitute a serious fire threat to urban areas or otherwise jeopardize the effectiveness of the community as a war center. Develops a plan of action designed to provide a more adequate degree of protection under possible emergency fire loads that may develop.

BUCK, CHARLES C., and FONS, W. L.
(34) 1935. The effect of direction of illumination upon the visibility of a smoke column. Jour. Agr. Res. 51(10): 907-918, illus.

Reports laboratory results indicating that the angle measured at the smoke between the sun and the observer determines the effect of the direction of illumination on the visibility of a smoke column, regardless of the azimuth of the sun. Little variation in visibility was noted in angles of 90° or less, but there was a marked increase of visibility at angles greater than 90°. Smoke is not visible when the source of illumination formed the background.

The visibility of an object is affected by the amount of suspensoid material in the atmosphere. When the sun is at an angle of 90° or less to the line of sight of the observer the decrease in visibility attributable to suspensoid may be caused largely by decreased light transmission. But when the angle exceeds 90° a further decrease in visibility results from the veiling brightness of the suspensoid material. Landscape visibility in the direction of the sun is thus decreased. Increased brightness of a smoke column viewed toward the sun is more than the veiling brightness of haze and the net effect is greater smoke visibility in that direction.

BUCK, CHARLES C., FONS, W. L., and COUNTRYMAN, C. M.
(35) 1948. Average fire damage from increased run-off and erosion on the southern California National Forests. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 25 pp., illus.

Predicts probable run-off and erosion damages expected after fires.

(36) 1948. Fire damage from increased run-off and erosion, Angeles National Forest. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 116 pp., illus.

Reports estimates of run-off and erosion damage after fire in a form suitable for current fire damage appraisal on individual watershed units of the Angeles National Forest. (One of a series, similar estimates for other forests given in items 37, 38, and 39.)

(37) 1948. Fire damage from increased run-off and erosion, Cleveland National Forest. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 88 pp., illus.

(38) 1948. Fire damage from increased run-off and erosion, Los Padres National Forest. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 107 pp., illus.

(39) 1948. Fire damage from increased run-off and erosion, San Bernardino National Forest. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 88 pp., illus.

BUCK, CHARLES C., and HUGHES, J. E.
(40) 1939. The solvent distillation method for determining the moisture content of forest litter. Jour. Forestry 37(8):645-651, illus.

The solvent distillation method for determining the moisture content of forest litter is based upon the principle that the boiling characteristics of a liquid change when it is boiled with another liquid with which it is immiscible.

The xylene distillation method combines speed and accuracy and permits standardization of results to a degree not obtainable by other methods in common use. The method is well adapted to routine moisture-content analysis and provides a means of checking and comparing results of studies involving fuel moisture content.

CASAMAJOR, PAUL, and WILSON, C. C.

(41) 1957. Portable chippers: answer to reducing slash fire hazard. Timberman, 58(7):50-52

Reports studies of the portable wood chipper's potentiality for reducing fire hazard and reviews other benefits which accrue from use of the chipper.

CHANDLER, CRAIG C.

(42) 1956. Integrating prevention into fire control planning. U.S. Forest Serv. Fire Control Notes 17(2):6-7.

Suggests the need for major re-evaluation of fire-control planning methods to integrate fire prevention into organization plans.

(43) 1957. "Light burning" in southern California fuels. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Res. Note 119, 2pp.

Fuel studies made during Operation Firestop in 1954 show that light burns accomplished little in the way of hazard reduction. These limited tests also indicate that more studies of brush as a fuel should be undertaken.

(44) 1960. Developing a measure for various man-caused fire risks. U.S. Forest Serv. Fire Control Notes 21(2):31-34.

Reports the role of statistics in fire prevention planning. Outlines the steps the U.S. Forest Service uses in California to measure the relative risk of fire from various types of forest use.

(45) 1960. Fire and slash. Redwood Region Conserv. Council Fire Prevention Com. Rpt. pp. 12-14.

Reports the problems connected with fire and slash and lists the questions most asked of researchers by forest managers. Indicates the basic research being conducted on slash problems by the Pacific Southwest Forest and Range Experiment Station.

(46) 1960. Historical note: "Santana" vs. "Santa Ana." Calif. Div. Forestry Newsletter 19(3, 4):19.

A brief note on how the river, the town, and the winds came to be called by two names, "Santana" and "Santa Ana."

(47) 1960. How good are statistics on fire causes? Jour. Forestry 58(7):515-517.

Analysis of the accuracy of published statistics of fire causes shows: (a) most fires of unknown origin are called "smoker";

(b) nearly all fires of unknown origin are attributed to "outsiders"; and (c) the average accuracy of attribution for all man-caused fires was 79 percent.

CHANDLER, CRAIG C.

(48) 1960. Measuring the people threat to forest management. Soc. Amer. Foresters Proc. 1959:131-132.

Thirty-eight owners of 2-1/2 million acres of private timberland in California were polled: recreation was encouraged on 200,000 acres, prohibited on 400,000 acres, and "tolerated" on the remainder. Direct expenditures for managing recreationists on private lands totaled $86,000, or 3-1/2 cents per acre per year.

(49) 1960. Slash weight tables for westside mixed conifers. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Tech. Paper 48, 21 pp., illus.

Lists the oven dry weight of slash for five common tree species, in pounds per tree and pounds per 1,000 board feet by species, d.b.h., and crown length. Provides additional tables for determining weight of cull logs and weight of trees smaller than 12 inches diameter at the stump.

(50) 1961. Fire behavior of the basin fire. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. 84 pp., illus.

Gives a detailed history of fire behavior as affected by fuels, weather, and topograhy. Local weather is documented by both surface and upper air observations. Discusses synoptic weather and fuels and reports on five specific fire behavior anomalies and the actual fire weather-fire behavior forecasts.

(51) 1961. Risk rating for fire prevention planning. Jour. Forestry 59(2):93-96.

Describes a system of risk rating designed to compare areas with radically different fire problems. The relative chance of a man-caused fire starting is postulated to be a function of four variables: weather, fuels, human use, and prevention effectiveness. Describes the process of measuring and compiling these variables and illustrates the computation of a risk index number.

CHANDLER, CRAIG C., and COUNTRYMAN, C. M.

(52) 1959. Use of fire behavior specialists can pay off. U.S. Forest Serv. Fire Control Notes 20(4):130-133.

Lists the requirements necessary for adequate operation of a fire behavior team on campaign fires, and outlines the services such a team can provide if properly organized.

CHANDLER, CRAIG C., and DAVIS, JAMES B.
(53) 1960. What do people know about fire prevention? U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Misc. Paper 50, 4 pp.

Reports on a study conducted by the University of Southern California to determine what forest-using groups know about fire prevention. Preliminary results indicate that local residents know more than outsiders, that fire prevention knowledge parallels general educational level, that most correct information is obtained by word-of-mouth, and that burning and campfire permit regulations are poorly understood.

(54) 1961. What do people know about fire prevention? U.S. Forest Serv. Fire Control Notes 22(1):9-12.

Same as item (46).

COFFIN, HARRY.
(55) 1959. Effect of marine air on the fireclimate in the mountains of southern California. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Tech. Paper 39, 30 pp., illus.

Reports observations and conclusions from a study of the incidence and effect of Catalina Eddy winds, moist marine air that extends over southern California in early summer and reduces fire hazard.

COLEMAN, E. A.
(56) 1953. Fire and water in southern California mountains. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Misc. Paper 3, 7 pp.

Floods normally follow fires in southern California watersheds except in years of below normal rainfall. Water yield is increased on burned watersheds, but is of an unusable form. An increase in summer flow on burned watersheds is due mainly to a reduction in riparian vegetation. Engineering works help to prevent flood damage but a major concern should be the protection of the mountains from fire.

COUNTRYMAN, C. M.
(57) 1953. A pocket type humidity indicator for use in fire prevention and control. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Misc. Paper 12, 1 p., illus.

Describes an indicator which has six spots representing six humidity levels. Variations in the color of the spots indicate the humidity level.

COUNTRYMAN, C. M.

(58) 1956. Fire season severity in 1955 on the Klamath National Forest. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Res. Note 103, 7 pp., illus.

Weather conditions in 1955 produced the most severe burning conditions ever experienced on the Klamath National Forest. How a severity index can be computed is explained.

(59) 1956. Old-growth conversion also converts fireclimate. Soc. Amer. Foresters Proc. 1955:158-160, illus.

Cutting a forest stand changes the local fire weather and therefore changes the fire-control job.

(60) 1957. California fire-weather severity in 1956. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Res. Note 118, 7 pp., illus.

A survey of the fire-weather severity in northern California shows that the 1956 weather was "easy" as compared to a 5-year average. But in southern California the fire-weather index climbed rapidly to a high level, indicating a heavy fire load.

(61) 1960. Fire environment and silvicultural practice. Soc. Amer. Foresters Proc. 1959:22-23.

Fire behavior is controlled by the environment in which the fire burns; as the environment changes so does the fire behavior. Silvicultural practice is one factor that can affect fire environment and, hence, fire hazard.

COUNTRYMAN, C. M., and COLSON, DeVER.

(62) 1958. Local wind patterns in Wildcat Canyon. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Tech. Paper 28, 12 pp., illus.

Shows some kinds of information that can be derived from fire-climate survey.

COUNTRYMAN, C. M., and CORNELIUS, D. R.

(63) 1957. Some effects of fire on a perennial range type. Jour. Range Mangt. 10(1):39-41.

Six years after a wildfire, cover density of the burned area was far less than that of an adjacent unburned area. Perennial grasses and bitterbrush were decidedly reduced on the burned plots, largely because of change in microclimate and closer grazing.

COUNTRYMAN, C. M., and FONS, W. L.

(64) 1950. Effect of litter type upon fuel-moisture indicator stick values. U.S. Forest Serv. Fire Control Notes 11(1): 20-21, illus.

Describes eight kinds of litter tested for their effects on fuel-moisture stick readings as compared to ponderosa pine needles. None of the fuel-moisture sticks exposed over the different litter types showed any significant difference in indicated moisture content. Ground cover of some type is advised to keep the sticks from being splashed with mud during heavy rain.

COUNTRYMAN, C. M., and INTORF, P. H.

(65) 1953. A fire season severity index for California National Forests. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Misc. Paper 14, 7 pp., illus.

Describes the factors and considerations in developing a severity index for the National Forests in California.

COUNTRYMAN, C. M, and SCHROEDER, M. J.

(66) 1958. Prescribed burn fireclimate survey 1-57. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Tech. Paper 29, 14 pp., illus.

Describes the results of a fireclimate survey of a prescribed burn in the lower foothills of the central Sierra Nevada. Observations showed wind speed on the lee side of a fire can increase under some conditions.

(67) 1959. Prescribed burn fireclimate survey 2-57. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Tech. Paper 31, 18 pp., illus.

Reports a fireclimate survey for a prescribed burn in the foothills of the central Sierras. Observations showed that fire behavior including the development of fire whirls may follow closely the wind flow pattern of the area. They also showed the effect of large scale weather changes on local weather patterns.

(68) 1959. Prescribed burn fireclimate survey 3-57. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Tech. Paper 34, 15 pp., illus.

Describes a fireclimate survey for a prescribed burn in the central coast area of California. Observations showed the development of strong downslope winds during the afternoon in the area. Fire behavior followed closely the predetermined wind flow pattern.

COUNTRYMAN, C. M., and SCHROEDER, M. J.

(69) 1959. Prescribed burn fireclimate survey 4-57. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Tech. Paper 35, 19 pp., illus.

Describes a fireclimate survey for a prescribed burn in a steep walled canyon in the Vaca Mountains. Observations suggest that air flow pattern in such a topographic situation may be extremely complex and may occur in "layers."

(70) 1960. Fire environment--the key to fire behavior. Fifth World Forestry Congress Proc. [In press.]

Illustrates some of the relationships of fire behavior to the environment in which the fire is burning. Describes the effect that silvicultural and wildland management practices have on fire environment and fire behavior.

COURT, ARNOLD.

(71) 1960. Evaluation of seeding trials. Jour. Irrig. and Drain. Div. Amer. Soc. Civil Engin. Proc. 1960:121-126.

Describes the results of three years of anti-lightning cloud-seeding operations in northeastern California and discusses the statistical design used to evaluate seeding with ground generators.

(72) 1960. Lightning fire incidence in northeastern California, 1945-56. U. S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Tech. Paper 47, 21 pp., illus.

Analysis of lightning fire records indicates that lightning causes more fires in northeastern California than in all the rest of the state combined. Reports timing, season, trend, and other details of lightning-fire incidence on public and private lands.

(73) 1960. Thunderstorm frequency in northern California. Amer. Met. Soc. 41(8):406-409, illus.

Records for 41 years show the greatest monthly frequencies of thunderstorms occur in winter along the coast, in summer in the Great Basin, and in late spring in the Central Valley. In the Central Valley area a secondary maximum in early autumn is particularly important in starting forest fires.

CRAFTS, A. S., BRUCE, H. D., and RAYNOR, R. N.

(74) 1941. Plot tests with chemical soil sterilants in California. Univ. Calif. Agr. Expt. Sta. Bul. 648, 25 pp., illus.

Reports on herbicidal behavior of sodium arsenite, arsenic trioxide, sodium chlorate, ammonium thiocyanate, borax, and colemanite. Graphs show percentage of kill and cumulative effects.

CRAFTS, A. S., and BUCK, CHARLES C.
(75) 1954. Herbicidal properties of arsenic trioxide. Univ. Calif. Agr. Expt. Sta. Bul. 739, 28 pp., illus.

Describes how 80 California soils responded to treatment in greenhouse, small field plots, and large scale operations. Arsenic trioxide (white arsenic) in three forms proved satisfactory as a means of soil sterilization and will destroy growth and prevent recurrence for periods of 5 to 10 years.

CURRY, J. R.
(76) 1933. Binocular telescopes in forest fire detection. Jour. Forestry 31(1):51-58, illus.

Reports test results of binoculars for fire lookout stations and recommends use of prismatic type binoculars of six or seven magnification with a wide field, high illumination, and excellent resolving power.

(77) 1934. Azimuth circle printer. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Res. Note 5, 1 p., illus.

Describes the technique, cost, and materials needed to print azimuth circles quickly and accurately on maps.

(78) 1934. Gowen elapsed time slide rule; the timekeeper's slide rule. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Res. Note 4, 2 pp.

Describes and explains the use of the slide rule.

(79) 1934. Indexes of forest fire control; National Forests Region 5, California, 1921-1933. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 25 pp., illus.

The indexes consist of average values for the 10-year base period, 1921-1930. The values for each year are expressed as a percentage of the base. The indexes considered are number of fires, area burned, cost of suppression, cost of prevention, and damage.

(80) 1936. Fire behavior studies on the Shasta Experimental Forest. U.S. Forest Serv. Fire Control Notes 1:2-30.

Reports on the fire behavior of over 300 test fires started in second-growth ponderosa pine stands, principally on level ground. Analysis of the data shows that wind, moisture content, and time have an important bearing on the dependent variable, rate-of-perimeter-increase. The analysis also shows the need to refine the measurement of the factors to fully evaluate their effects.

CURRY, J. R.

(81) 1936. Use of mil scale binoculars in fire detection. U.S. Forest Serv. Fire Control Notes 1:37-38, illus.

Describes mil scale binoculars used in California Region lookouts to help fire finders estimate fire size more accurately.

(82) 1937. The future of fire control. U.S. Forest Serv. Fire Control Notes 1(5):255-257.

Explains the need for reorganization and expansion of fire control administration and for basic research.

(83) 1938. Forest fire danger rating in the California Region, U.S. Forest Service. Fourth Rural Fire Inst. Proc. 1938:60-63.

Considers the development of the California forest fire danger rating and indicates the degree of organization required in forest fire control under certain fire danger conditions.

(84) 1938. The field of forest-fire protection. U.S. Forest Serv. Fire Control Notes 2(1):1-6, illus.

Contends that the term "forest fire protection" should include not only the strictly fire control activities of prevention, presuppression, and suppression but also fire damage, fire behavior, and fire economics. Presents a classification of forest fire activities.

CURRY, J. R., and BRUCE, H. D.

(85) 1935. Instructions in the use of diesel oil in killing [illegible]ing stumps in California firebreaks. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 5 pp.

Describes how, when, where, and how much diesel oil should be sprayed on sprouting stumps.

CURRY, J. R., and FONS, W. L.

(86) 1938. Rate of spread of surface fires in the ponderosa pine type of California. Jour. Agr. Res. 57(4):239-267, illus.

Analyzes the rate of spread of about 160 test fires in even-aged, second-growth ponderosa pine stands. The variables measured were size of fire, moisture content of fuel, wind velocity, time, and slope. Curves were drawn from the data and empirical formulas derived which permit estimates of rate of perimeter increase or total perimeter at any time interval within limits of the data.

CURRY, J. R., and FONS, W. L.
(87) 1940. Forest fire behavior studies. Mech. Engin. 62(3): 219-225, illus.

The study of the phenomenon of fire spread consists of the recognition of controlling variables, the development of methods and techniques of measuring these variables, and the evaluation--both individually and jointly--of the influence of the variables on the rate of spread.

Results of studies in this field have been incorporated into a series of indexes and are being used as part of a systematic method of rating fire danger on National Forests in California.

CURRY, J. R., GRAY, L. G., and FUNK, I. C.
(88) 1940. Forest fire-danger rating and its application in California. Jour. Forestry 38(11):855-866, illus.

Analyzes the problem of rating forest fire danger and what constitutes ideal data and methods, and describes a scheme to arrive at these data and methods.

CURRY, J. R., and IKENBERRY, G. J.
(89) 1934. Instructions in the use of sodium arsenite in killing sprouting stumps on firebreaks. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 8 pp.

Gives detailed instructions on the proper methods of preparing, applying, and storing the chemicals needed.

DAVIS, JAMES B.
(90) 1960. Air drop tests--Willows, Santa Ana, Ramona, 1955-1959. Calif. Div. Forestry, 22 pp., illus.

Gives a brief history of air tankers and describes air tanker drop tests conducted from 1955-1959. Concludes from the tests that: (a) viscosity reduces drift, (b) fall speed is not increased by weight; borate and bentonite fall alike, (c) drift increases with both height and speed, (d) big gates give better drops, and (e) larger carrying capacity and maneuverability depends on the fire situation.

DAVIS, JAMES B., and CHANDLER, CRAIG C.
(91) 1960. What people think about forest fire law enforcement. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Misc. Paper 51, 4 pp.

Reports the results of study of fire law violators on the San Bernardino National Forest. Most were well-meaning individuals who did not realize they were making a mistake. This lack of awareness was a general characteristic of the group. Their traffic citation frequency was also high and their knowledge of forest surroundings was low.

DAVIS, JAMES B., DIBBLE, DEAN L., and PHILLIPS, CLINTON B.
(92) 1961. Firefighting chemicals--new weapons for the fire suppression crew. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Misc. Paper 57, 27 pp., illus.

Field tests of viscous water, viscous diammonium phosphate, and bentonite foam dropped by tanker crews on 40 forest fires indicate that (a) viscous water was more effective than plain water for controlling fires in most forest fuels and in keeping them from rekindling, (b) a thick gel made with algin and calcium chloride was even more effective than ordinary viscous water under the same conditions, (c) foaming bentonite was superior to plain water for fires burning in heavy fuels but permitted fire to creep through matted grass and leaves, and (d) diammonium phosphate solution thickened with a viscosity agent can make some forest fuels almost fireproof for a long time. Gives information on costs per gallon and on mixing, handling, and storing.

DIBBLE, DEAN L.
(93) 1960. The fireclimate survey trailer. U.S. Forest Serv. Fire Control Notes 21(4):116-120, illus.

Describes the conversion of a two-wheeled trailer to a mobile unit for carrying meteorological recording instruments. The trailer is designed for use in fire environment studies, fires, or wherever 24-hour weather observations are needed.

DIBBLE, DEAN L., RICHARDS, S. S., and STECK, L. V.
(94) 1961. Testing and evaluating chemical fire retardants in the laboratory. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Misc. Paper 59, 11 pp., illus.

Describes the laboratory testing procedures used to screen proposed chemical fire retardants. This first step in a study program includes laboratory, field, and operational testing before a new material is accepted for practical application.

DUNNING, DUNCAN.
(95) 1929. Fire on the foothills; the problem of controlling fires in the marginal brush lands of California. Calif. Countryman 15(7):6, 16, illus.

Lists and explains the current problems and research projects needed to solve brushland fire problems.

ELY, J. B., and JENSEN, A. W.
(96) 1955. Air delivery of water helps control brush and grass fires. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Forest Res. Note 99, 12 pp., illus.

Describes the tests of an agricultural biplane as an aerial tanker for support of ground fire-fighting forces. Water was dropped on fires on the Mendocino National Forest during the 1955 fire season, and calibration flights were made at the Willows airport dropping both water and fire retarding chemicals.

ELY, J. B., and JENSEN, A. W.
(97) 1956. Air delivery of water helps control brush and grass fires. U.S. Forest Serv. Fire Control Notes [illegible] 22-25.

Reports the successful fire-testing of Stearman air tanker and urges the preparation of operational guidelines.

ELY, J. B., JENSEN, A. W., CHATTEN, L. R., and JORI, H. W.
(98) 1957. Air tankers--a new tool for forest fire fighting. U.S. Forest Serv. Fire Control Notes 18(3):103-109, illus.

Reports the successful fire-testing of the Stearman air tanker and urges the preparation of operational guidelines.

FENNER, R. L.
(99) 1953. A safe, cheap, and effective forest fire grenade. U.S. Forest Serv. Fire Control Notes 14(2):22-24, illus.

Describes the making and application of a general purpose forest fire grenade.

FENNER, R. L., ARNOLD, R. KEITH, and BUCK, CHARLES C.
(100) 1955. Area ignition for brush burning. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Tech. Paper 10, 10 pp., illus.

Outlines methods and precautions for the use of area ignition system of firing for safer, more effective controlled burns in land clearing. Describes a brush-smashing technique for fuel preparation before firing.

FENNER, R. L., ARNOLD, R. KEITH, BURCHAM, L. T., and GRAH, R. F.
(101) 1951. Use of fire in land clearing. Calif. Agr. 5(3-7): 9-15, illus.

Describes results of investigations of the effectiveness, safety, and cost of controlled burning as a tool for land clearing. Makes no attempt to provide one formula for prescribed burning in California. Each fire is considered an individual case to be planned on the ground.

FENNER, R. L., and BENTLEY, J. R.

(102) 1960. A simple pyrometer for measuring soil temperatures during wildland fires. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Misc. Paper 45, 9 pp., illus.

Describes a simple, inexpensive pyrometer developed for gathering temperature data on burned wildlands. Temperatures from 150° to 1150°F. can be recorded.

FIRESTOP

(103) 1954. Organization plan and work schedule. Firestop Exec. Com. Prog. Rpt. 1, 9 pp.

Briefly outlines objectives, individual and organization responsibilities, and work plan.

(104) 1954. Status--June 1. Firestop Exec. Com. Prog. Rpt. 2, 9 pp.

Reports accomplishments of Operation Firestop and the proposed test program.

(105) 1954. Field Review. Firestop Exec. Com. Prog. Rpt. 3, 9 pp., illus.

Relates objectives and origin of Operation Firestop. Describes the five groups of field studies and gives preliminary summary of results. Includes illustrations of field operations.

(106) 1955. Fire retardants--I. Firestop Exec. Com. Prog. Rpt. 4, 12 pp., illus.

Describes laboratory procedures aimed at evaluating the effectiveness of retardants.

(107) 1955. Fuel studies--L. Firestop Exec. Com. Prog. Rpt. 5, 15 pp., illus.

Presents a method of measuring the volume and vertical distribution of grass and chaparral fuels. Tons of green and dead fuel per acre are shown for sample plots.

(108) 1955. Seasonal changes in chaparral moisture. Firestop Exec. Com. Prog. Rpt. 6, 7 pp., illus.

Relates variations in green foliage to topography and changes in climate. Such information, when considered along with knowledge of fluctuations in the moisture content of dead materials, can help forecast forest fire behavior.

FIRESTOP

(109) 1955. A wind machine and fire control. Firestop Exec. Com. Prog. Rpt. 8, 8 pp., illus.

Axial-flow blowers may aid in backfiring, but the probability of spot fires and danger to the operator prohibit their use for holding a spreading fire against the wind.

(110) 1955. Aerial firefighting--bulk water drop by fixed wing aircraft. Firestop Exec. Com. Prog. Rpt. 9, 13 pp., illus.

Describes previous work by several agencies on dropping water and retardants on fire from aircraft. Also reports on water drops from a modified TBM bomber.

(111) 1955. Aerial firefighting--the helitanker. Firestop Exec. Com. Prog. Rpt. 10, 5 pp., illus.

Describes a helicopter equipped to combine the advantages of the tank, pump, and hose of a small ground tanker with the mobility and speed of the helicopter; suggests uses on the fire line and for civil defense purposes.

(112) 1955. Lightweight pipe for water supply. Firestop Exec. Com. Prog. Rpt. 11, 6 pp., illus.

Describes the use of quick-coupling aluminum pipe and its suitability for rapid delivery of large quantities of water to fires over relatively rough terrain and long distances.

(113) 1956. Backfire line with chemicals. Firestop Exec. Com. Prog. Rpt. 13, 6 pp., illus.

Describes a method of smashing brush with a tractor and then spraying a chemical retardant to prepare emergency backfire line in brush fuels.

(114) 1956. Fire behavior studies. Firestop Exec. Com. Tech. Rpt. 1, 85 pp., illus.

Reports on studies of instrumentation and experimental techniques used in fire behavior research. Eleven tests were made of equipment and techniques to obtain the overall energy balance of a fire and to analyze the convection column of fire. Recommendations for further research are included.

(115) 1956. The wind survey. Firestop Exec. Com. Tech. Rpt. 2, 18 pp., illus.

Reports on procedures and instrumentation developed for a 3-month intensive study of air movement in a typical mountain canyon. Gives recommendations for future wind survey .

FONS, W. L.

(116) 1940. An Eiffel-type wind tunnel for forest research. Jour. Forestry 38(11):881-884, illus.

Describes the Eiffel-type wind tunnel and its possibilities for the study of forest fire behavior and other aspects of forest fire research.

(117) 1940. Influence of forest cover on wind velocity. Jour. Forestry 38(11):881-886, illus.

Reports the variation of wind velocity as influenced by three cover types: grassland, brush, and even-aged ponderosa pine.

The shapes of the wind-velocity curves for each cover type are distinctive. The results indicate that wind velocities at any two heights bear a linear relation to each other. Wind velocity in a forest usually is not a constant percentage of the velocity above the crowns, but is greatly reduced at the top of the crowns and remains nearly constant in the canopy.

(118) 1946. Analysis of fire spread in light forest fuels. Jour. Agr. Res. 72(3):93-121, illus.

Describes the analytical derivation of an equation expressing rate of fire spread through a forest fuel as a function of the basic variables pertaining to the atmosphere, the arrangement of the fuel bed, and the physical properties of fuel particles. The theory developed from the analysis and expressed in equation form indicates the important factors that control spread and how each operates. The analysis will find its most important use in serving as a working hypothesis and guide in further fire behavior research.

(119) 1950. Heating and ignition of small wood cylinders. Indus. and Eng. Chem. 42(10):2130-2133, illus.

Describes the effects of initial temperature, moisture content, and size of the wood on time of ignition as signified by the appearance of flame. The minimum furnace temperature at which ignition occurs with a flame was 650°F.; that at which charcoal glows was 450°F.

(120) 1950. Wet water for forest fire suppression. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Res. Note 71, 5 pp.

Discusses the advantages of wet water over plain water for flame suppression and mop-up work.

FONS, W. L.
(121) 1961. Rate of combustion from free surfaces of liquid hydrocarbons. Combustion and Flame 5(3):283-287, illus.

Presents results of laboratory experiments in which liquid hydrocarbons were burned in circular pans to learn the influence of diameter of the fuel surface on the rate of combustion.

FONS, W. L., BRUCE, H. D., and McMASTERS, A. W.
(122) 1960. Tables for estimating direct beam solar irradiation on slopes at 30° to 46° latitude. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. 298 pp., illus. (Limited distribution.)

Presents data for estimating the direct beam solar radiation on areas of the earth's surface for different aspects and slopes, for latitudes 30°N. to 46°N. and for various times of the day and year.

FONS, W. L., BRUCE, H. D., PONG, W. Y., and RICHARDS, S. S.
(123) 1960. Project Fire Model, summary progress report, period Nov. 1, 1958 to April 30, 1960. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. 56 pp., illus.

The project developed a laboratory-scale model of a steady-state, free-burning fire in solid fuel. The model uses a crib of wood sticks on a movable bed. An approximate heat balance, accounting for 91 percent of the heat energy, has been attained, and data have been collected on some fuel and environmental parameters that govern the combustion.

(124) 1960. Project Fire Model, fifth progress report, May 1, 1960 to Aug. 1, 1960. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. 8 pp.

Reports on activities including tests performed and their results, papers presented, equipment purchased, and plans for the next quarter.

(125) 1960. Project Fire Model, sixth progress report, Aug. 1, 1960 to Nov. 1, 1960. U.S. Forest Serv. Pacific Southwest Forest & Range Expt. Sta. 13 pp., illus.

Reports on activities including tests performed and their results, papers presented, equipment purchased, and plans for the next quarter's work.

FONS, W. L., BRUCE, H. D., and PONG, W. Y.
(126) 1960. A steady-state technique for studying the properties of free-burning wood fires. Fire Res. Abs. and Rev. 2(1): 26-30.

Describes the development of a suitable bed of solid fuel and of a laboratory study technique with the ultimate objective of determining model laws of the rate of spread and other properties of wood fires.

FONS, W. L., and McBRIDE, R. S.
(127) 1950. Wet water for pretreating litter fuels. U.S. Forest Serv. Fire Control Notes 11(2):26-27.

"Wet water" evaporates at a faster rate than plain water from light fuels for the first 20 minutes. After 1 hour, fuel sprayed with wet water had a higher moisture content than fuel sprayed with plain water.

GOWEN, G. M., CURRY, J. R., and BROWN, A. A.
(128) 1936. Visible-area mapping of lookout points; methods and techniques. U. S. Forest Serv. Calif. Forest & Range Expt. Sta. 15 pp., illus.

Describes and evaluates several methods of making visible area maps for lookout points.

HANSON, P. D., and ABELL, C. A.
(129) 1941. Determining the desirable size of suppression crews for the National Forests of northern California. U.S. Forest Serv. Fire Control Notes 5(3):156-160, illus.

Analyzes the records of some 8,400 fires in northern California from 1925 to 1937 and estimates the optimum size of initial attack crews according to different rates of spread.

IKENBERRY, G. J., BRUCE, H. D., and CURRY, J. R.
(130) 1938. Experiments with chemicals in killing vegetation on firebreaks. Jour. Forestry 36(5):507-515.

Describes experiments conducted to determine the possibility of reducing cost of firebreak maintenance through the use of chemicals.

JENSEN, ARTHUR W., and SCHROEDER, M. J.
(131) 1958. A new measure of the build-up for fire danger rating in California. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Res. Note 133, 5 pp., illus.

Describes the development of a new method of fire danger rating using the moisture content of large logs to estimate buildup.

KOTOK, E. I.
(132) 1927. A county assessor lists fire losses. Forest Worker 3(6):14.

Lists dollar losses in timber valuation, wages, and manufactured products, and also considers the suppression costs as money that could have been used on schools and roads.

KOTOK, E. I.

(133) 1929. Establishing "relative hazard" of forest types. West. Forestry and Conserv. Assn. Proc. 1929:7-8. (Also appeared in West Coast Lumberman 56(4):25-26 under the title "Relative risk and hazard.")

Relates factors that must be evaluated to develop a fire protection organization and to determine insurance rates on forest land. Says "risk" (the possibility of a fire starting because of fuels, weather, and carelessness), "hazard" (the inflammability of the fuel, which affects the rate of fire spread), and "damage" (the effects of fire on the value of the property) should be integrated to determine the "liability" for a given area. Preliminary survey studying variations in the risk and hazard factors was made.

(134) 1930. Fire, a problem in American forestry. Sci. Monthly 31: 450-452.

Describes the problem of forest fire from the standpoint of wood production, forest regeneration, water resources, and damage by fire to certain forest types. Relates the lack of public support for fire prevention.

(135) 1933. Fire, a major ecological factor in the pine region of California. Fifth Pacific Sci. Cong. Proc. 1933:4017-4022.

Explains the influence of foothill fires on ecological changes. The general characteristics of the pine forests are listed to indicate the silvical nature of the forest and its response to fire.

KOTOK, E. L., KELLEY, E. W., and EVANS, C. F.

(136) 1933. U.S. Forest Service. A national plan for American forestry. Protection against fire. pp. 1395-1414, illus. Washington: U.S. Government Printing Office.

Reviews the forest fire situation in the United States and explains the objectives of fire control and how they have been met. Describes the basic needs and essential parts and functions of a national fire-control program.

McBRIDE, R. S.

(137) 1950. Corrosion of metals by wet water. U.S. Forest Serv. Fire Control Notes 11(2):31.

Tests on 24-gage iron and galvanized iron indicate that galvanized iron is more readily corroded by wetting agents than iron and that the addition of potassium dichromate to plain water or to a wetting agent solution decreases corrosion.

MILLER, HARRY R., JR.
(138) 1956. Chemical fire retardants for wild land fire control. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Res. Note 105, 5 pp. (Also appeared in Fire Control Notes 17(4):25-28.)

Describes tests using sodium calcium borate as a fire-retarding chemical during 1955 fire season, and includes conclusions and recommendations.

MILLER, HARRY R., JR., and PHILLIPS, CLINTON, B.
(139) 1958. Preliminary tests of some new fire retardants. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Res. Note 140, 4 pp.

Describes laboratory tests of a few potential forest fire retardants, notes the study yet required on these materials, and lists the characteristics of an ideal fire retardant.

MILLER, HARRY R., JR., and REINECKER, H. P.
(140) 1958. Air tanker report--California, 1957. U.S. Forest Serv. Fire Control Notes 19(2):53-56, illus.

Describes the effectiveness of air tankers on forest fires in California in 1957 and some of the limitations noted by field personnel.

MILLER, H. R., and WILSON, C. C.
(141) 1957. A chemical fire retardant--results of field trials using sodium calcium borate on forest fires in 1956. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Tech. Paper 15, 20 pp., illus.

Field tests showed sodium calcium borate as a useful tool and emphasized the need for equipment to simplify and speed up the mixing of chemicals for ground and air tankers. The needs of firefighters for operational guidelines are given.

MURPHY, JAMES.
(142) 1957. Helicopter message or cargo drop-and-pickup kit. U.S. Forest Serv. Fire Control Notes 18(4):152-155, illus.

Shows how a drop-and-pickup unit for helicopters can solve communication problems arising when use of radio is limited, if the crew has been properly instructed in safety practices.

(143) 1958. Ground operations for helicopters. U.S. Forest Serv. Fire Control Notes 19(2):74-78, illus.

Describes helicopter ground crew organization and duties and how to locate, construct, and operate heliports and helispots safely and efficiently.

MURPHY, JAMES.

(144) 1958. Helitack crews pay off in California. U.S. Forest Serv. Fire Control Notes 19(2):94-96.

Describes the use of specially trained Helitack crews in California in 1957 to suppress small remote forest fires in their early stages and aid on large fires.

(145) 1958. Training the Helitack crew. U.S. Forest Serv. Fire Control Notes 19(2):91-93, illus.

Outlines a suggested plan to train crews in using the helicopter safely and efficiently for fire control work.

(146) 1959. The helijump--the research and development of the helicopter hover jump technique. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Misc. Paper 32, 22 pp., illus.

Describes the research and development of the "hover-jump" technique, the 4-pass helijump operation, and lists recommendations for helijump protective suit.

(147) 1959. Helispot location and construction. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Misc. Paper 31, 18 pp., illus.

Describes practical methods of helispot location and construction in mountain topography.

(148) 1959. Safety rules for Helitack. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Coop. Rpt. 7 pp., illus.

A compilation of safety precautions to be remembered and practiced by the heliport air service manager, the Helitack crewman, and the helicopter pilot.

(149) 1960. California Helitack report--1958. U.S. Forest Serv. Fire Control Notes 21(1):1-4.

Reviews three years of progress in a cooperative research and development program aimed at integrating the helicopter for fire control.

(150) 1960. Changes in the Helitack training plan. U.S. Forest Serv. Fire Control Notes 20(3):77-79, illus.

Describes changes in Helitack training plans with the introduction of turbo-jet helicopters and the use of smaller helicopters for dropping cargo. Emphasizes how regular ground firefighters have been used to supplement regular Helitack crews.

MURPHY, JAMES.

(151) 1960. The helicopter and the dead man's curve. U.S. Forest Serv. Fire Control Notes 20(1):1-2, illus.

Emphasizes the importance of recognizing the take-off and landing limitations of helicopters, particularly in heavy timber.

NEUNS, A. G.

(152) 1950. Chemicals for fire prevention. U.S. Forest Serv. Fire Control Notes 11(1):9-11, illus.

A soil sterilization agent is needed to discourage the regrowth of plant cover on certain "fireproofed" areas. The use of five chemicals for this purpose is described.

(153) 1950. Let's change our headlight circuit. U.S. Forest Serv. Fire Control Notes 11(3):17-19, illus.

Tests of headlight circuits, two parallel and one series, for current flow for 8-hour periods indicate that the series circuit is the best of the three.

(154) 1950. A training course in fire behavior. U.S. Forest Serv. Calif. Forest & Range Expt. Sta., 21 pp., illus.

The material in this instruction guide was compiled from a training course prepared by R. W. Asplund and deals with the fundamental principles of fire and their specific application to the behavior of forest fires.

(155) 1950. Water vs. fire. Fighting forest fires with water, U.S. Forest Serv. Calif. Region. 38 pp., illus.

Shows the many ways to suppress fire in forest areas with water, and how to make a little water do a big job.

(156) 1952. Woody plant control along roads in Shasta National Forest. Down to Earth 8(1):14-15, illus.

Describes the control of sprouting brush species on the Shasta National Forest with sprays of 2,4-D, and 2, 4, 5-T.

(157) 1958. Four-purpose enclosure card for training films. U.S. Forest Serv. Fire Control Notes 19(3):103-105, illus.

A specially designed card fits into film can with the training movie and serves as an outline of the film's contents, as an advanced notice to be mailed, as a file copy for planning training sessions, and as a brief guide on how to use a motion picture for training.

NEUNS, A. G., and SIMPSON, ALBERT.

(158) 1951. The use of 2, 4-D and 2, 4, 5-T for brush control on California forest roads and trails. U.S. Forest Serv. Calif. Forest & Range Expt. Sta., 27 pp.

Records costs and results of spraying 2, 4-D and 2, 4, 5-T at varying strengths on brush growing along roads and trails; includes guides for the use of the herbicides for brush control.

OLSEN, JAMES M.

(159) 1959. Setting up a green fuel moisture study. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Misc. Paper 40, 3 pp., illus.

Describes the research techniques involved in setting up a study of the moisture of green chaparral fuel on the San Dimas Experimental Forest as one phase of the Fuel-Break program.

(160) 1960. 1959 green fuel moisture and soil moisture trends in southern California. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Res. Note 161, 8 pp., illus.

Correlates foliage moisture changes with soil moisture changes.

(161) 1960. Cistus, fuel moisture, and flammability. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Res. Note 159, 2 pp., illus.

A study of foliage moisture variations in cistus plantations on the San Bernardino National Forest showed no appreciable difference from moisture variations of a native brush species.

PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION.

(162) 1960. Drilling--a good method of sowing grasses on fuel-breaks. U.S. Forest Serv. In-Program Fuel-Break Release Rpt. 3, 3 pp.

In southern California, sowing with a drill is the best way to obtain the good grass stands needed for soil protection on fuel-breaks. Where to use a drill, what grasses to use, costs, and where to broadcast sow are covered.

(163) 1960. Fuel-break 1958-1960 demonstration and action projects. U.S. Forest Serv. In-Program Fuel-Break Release, 5 pp., illus.

Gives the description, location, and a short summary of each project.

PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION

(164) 1960. Highlights from broadcast spraying of chamise sprouts in southern California. U.S. Forest Serv. In-Program Fuel-Break Release Fuel-Break Rpt. 6, 3pp.

Three years' experience in spraying regrowth of chamise-sage brush types has shown that broadcast chemical spraying by either tractor boom or helicopter is effective. Application rate, costs, and spraying times are considered.

(165) 1960. How much does it cost to spray brush on southern California fuel-breaks? U.S. Forest Serv. In-Program Fuel-Break Release Fuel-Break Rpt. 5, 2 pp.

Reports cost estimates based on 3 years' experience with broadcast chemical spraying of fuel-breaks and with type conversions. Helicopter and tractor-boom spraying are described.

(166) 1960. A new kind of fuel-break report. U.S. Forest Serv. In-Program Fuel-Break Release 1 p.

Announces a plan to send a 1-page demonstration and action project to cooperators soon after the data is accumulated.

(167) 1960. Pacific Telephone and Telegraph right-of-way (fuel-break). U.S. Forest Serv. In-Program Fuel-Break Release 1 p.

Describes a cooperative operation in which 100 acres of brush along telephone line right-of-way were sprayed with 2, 4-D and 2,4,5-T. Gives cost per acre.

(168) 1960. Promising grasses for southern California fuel-breaks. U.S. Forest Serv. In-Program Fuel-Break Release Rpt. 4, 4 pp.

Summarizes recommendations from 2 years of fuel-break work. The recommendations are for specific sites. The grasses are evaluated as to ability to provide protective soil cover.

(169) 1960. Sitton Peak fuel-break. U.S. Forest Serv. In-Program Fuel-Break Release 1 p.

On this new break within the 1958 Stewart Burn, about 2 miles of ridge top covering 90 acres, was sprayed by helicopter in 1960. The area was sown with ryegrass, but the cover became mainly resident species.

(170) 1960. Spanish Canyon fuel-break. U.S. Forest Serv. In-Program Fuel-Break Release 1 p.

Describes the respray of a fuel-break: costs, application, and reasons.

PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION

(171) 1960. Testing firefighting chemicals with ground equipment.
U.S. Forest Serv. 7 pp., illus.

Field study to test laboratory results showed that making water viscous improves its fire fighting characteristics. It also appears that thickening certain chemical fire retardants may improve their effectiveness. Water, bentonite slurry, bentonite foam, viscous water, and viscous diammonium phosphate were used in these tests.

(172) 1960. Testing firefighting chemicals with ground equipment.
U.S. Forest Serv. Mid-fire Season Operational Prog. Rpt.
5 pp.

At the mid-point of California's fire season, foaming bentonite, viscous water, and viscous diammonium phosphate were tested on 23 fires. The performance of the various materials is discussed and information is given on handling techniques and operational problems.

(173) 1960. Topanga Canyon fuel-break. U.S. Forest Serv. In-Program
Fuel-Break Release 1 p.

Reports on broadcast spraying of 6 miles of ridgetop burned during the 1958 Topanga Canyon fire, by tractor and helicopter in 1959, and by helicopter in 1960. Chamise appears to be well controlled, but hand spraying is needed to kill sumac and scattered plants of other species. A good cover of annual plants is developing.

(174) 1960. Trabuco Oaks 1958-1960. U.S. Forest Serv. In-Program
Fuel-Break Release Rpt. 2, 3 pp.

Reports on a fuel-break demonstration area in which chemicals were successfully used to control the brush coming in on a burned area. Costs and spraying dates are covered.

PHILLIPS, CLINTON B.

(175) 1960. Fighting forest fires from the air. Soc. Amer. Foresters
Proc. 1959:137-140, illus.

Describes the rapid expansion in the use of air tankers, retardants, and helicopters for forest firefighting since 1954 and emphasizes that air attack is primarily a tactical support operation.

PHILLIPS, CLINTON B., and MILLER, HARRY R., JR.

(176) 1959. Swelling bentonite clay--a new forest fire retardant.
U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta.
Tech. Paper 36, 30 pp., illus.

Summarizes results of laboratory and field tests of swelling bentonite clay, a new forest fire retardant. Describes the technical characteristics of bentonite and suggests how to store, mix, and pump it.

PHILLIPS, CLINTON B., and MILLER, HARRY R., JR.

(177) 1959. Using swelling bentonite clay as a fire retardant. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. 11 pp., illus.

Describes some characteristics of swelling bentonite clay which make it effective as a forest fire retardant and suggests how to store dry bentonite powder and how to mix, store, and transfer bentonite slurry.

(178) 1960. A new forest fire retardant--swelling bentonite clay. Jour. Forestry 58(12):948-951, illus.

Summarizes results of laboratory and field tests of swelling bentonite clay and describes some of the characteristics which make it effective as a fire retardant.

PIRSKO, ARTHUR R.

(179) 1958. Red, white or blue--wear an extra shirt on the fireline. U. S. Forest Serv. Fire Control Notes 19(3):102.

More than 99 percent of the heat from burning forest fuels is in the invisible infrared region of the spectrum; therefore the color of firefighters' clothing is less important than protection by two layers of clothes.

(180) 1959. Does weather influence urban fires? Fire Engin. 112(10): 938-939, 1009, illus.

Outside relative humidity in summer and dew point temperature in winter are shown to affect the moisture content of fine fuels inside buildings. The fluctuation of fuel moisture content is correlated with frequency of urban fires. An urban fire danger rating is proposed to guide fire administrators.

(181) 1960. 1960 fire weather severity in California. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Misc. Paper 54, 14 pp., illus.

Uses of the new ignition and fire load indexes of California fire danger rating to explain the severity of the 1960 fire season. A detailed analysis of four areas showed the daily ratings for ignition, burning, and fire load indexes. Severe fire behavior is shown to be related to high daily indexes.

(182) 1961. An alinement chart for perimeter increase of fires. U.S. Forest Serv. Fire Control Notes 22(1):1-4, illus.

Presents an alinement chart to eliminate arithmetical computations associated with studies of rate of fire spread. The chart corrects size at attack in acres and elapsed time in minutes to perimeter increase in chains per hour. Correction factors for the shape of burned areas are provided.

PIRSKO, ARTHUR R.
(183) 1961. Selecting fire control planning levels by burning index frequencies. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Misc. Paper 55, 7 pp., illus.

Reports that the level of protection is most logically tied to a preselected probability level of fire weather conditions described by a burning index. Outlines a procedure that rates distinctive areas and provides a method for changing levels of protection as management is intensified.

(184) 1961. Why tie fire control planning to burning index? U.S. Forest Serv. Fire Control Notes 22(1):16-19, illus.

Reports how the burning index indicates the relative rate of spread and intensity of fires, and describes the potential job load associated with fire suppression. Describes the interrelations of men, time, and the burning index. Relates the effect of prompt initial attack on the total number of firefighters needed.

PIRSKO, ARTHUR R., and STECK, L. V.
(185) 1961. Evaluation of liquid nitrogen and solid carbon dioxide as forest fire suppressants. U.S. Forest Serv. Fire Control Notes 22(4):120-122, illus.

Both liquid nitrogen and solid carbon dioxide were tested as suppressants on small crib fires in and outside the laboratory building. Neither material proved to be effective in extinguishing deep-seated fires.

PLUMB, T. T.
(186) 1961. Sprouting of chaparral by December after a wildfire in July. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Tech. Paper 57, 12 pp., illus.

Sprouts emerged from many shrubs within 10 days after the fire, but sprouting varied by species and location. Most early sprouting occurred near the base of slopes and in moist draws and stream channels. By December the dominant species, chamise and scrub oak, had produced only a limited volume of foliage.

PLUMB, T. R., and BENTLEY, J. R.
(187) 1960. Rate of broadcast 2,4-D spraying on second-year chamise sprouts. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Res. Note 163, 7 pp., illus.

Describes optimum application rates of 2,4-D hormone spray for controlling 2-year-old chamise sprouts in a burned-over area; 2,4-D alone appeared as effective pound for pound as a mixture of 2,4-D and 2,4,5-T.

REIFSNYDER, W. E.
(188) 1955. Wind profiles in a small isolated forest stand. Forest Sci. 289-297, illus.

Reports data on wind velocity measured in an artificially created stand of 145 ponderosa pines. Maximum attenuation of wind by tree crowns was 50 to 70 percent. Results from this model study are compared with profiles from work of other investigators.

ROBINSON, LEWIS H.
(189) 1960. An evaluation of three seasons of anti-lightning operations in California. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Res. Note 169, 8 pp.

Summarizes an evaluation of the 1957, 1958, and 1959 cloud seeding operations in California conducted with ground generators. Suggests that plans for a routine operation program for seeding from the ground be discontinued.

ROGERS, D. H.
(190) 1942. Measuring the efficiency of fire control in California chaparral. Jour. Forestry 40(9):697-703, illus.

Describes the relation between fire history and potential size of fire in chaparral. Offers a method of using this information to appraise the fire control and protection job from year to year.

ROWE, P. B., COUNTRYMAN, C. M., and STOREY, H. C.
(191) 1954. Hydrologic analysis used to determine effects of fire on peak discharge and erosion rates in southern California watersheds. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 49 pp., illus.

Describes the hydrologic analysis used in one phase of a study to appraise the flood and erosion damage resulting from watershed fires in southern California.

SAMPSON, A. W., and KOTOK, E. I.
(192) 1929. Burning vs. exclusion of fires on grass, chaparral, and forest lands. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 5 pp.

Describes the possible affect of four different burning methods on several vegetation types. Considers policies, research and vegetation studies that must be carried out before positive statements on burning can be made.

SAUER, F. M., and SCESA, S.
(193) 1954. Possible effects of free convection on fire behavior--laminar and turbulent line and point source of heat. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Tech. Paper 8, 47 pp., illus.

Reviews theories of free convection from point and line sources of heat for both laminar and turbulent flow. These theories are applied to atmospheric diffusion problems by appropriate changes. The relation of these theories to the convective flow field above a surface fire is presented. Only the thermal problem is considered, and no attempt is made to include combustion effects.

SCHROEDER, MARK J.

(194) 1960. Humidity patterns at middle elevations in the coastal mountains of southern California. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Res. Note 165, 6 pp., illus.

Describes four types of relative humidity patterns observed at a fireclimate station located at 1,910 feet on the coast side of the southern California mountains, and relates these patterns to the height of the moist marine-air layer.

(195) 1961. Down-canyon afternoon winds. Amer. Met. Soc. Bul. 42(8): 527-542.

In east-facing canyons in the coastal mountains of California the daytime thermal up-canyon winds are frequently replaced, usually in early afternoon, by a moderately strong down-canyon wind. The same type of wind has also been noted in the western foothills of the Sierra Nevada. This shift in the wind to down-canyon is important in wildland fire control and has been a factor in some fire fighting fatalities. Results of a fire-climate survey conducted in northwestern San Diego County to study these winds show that, in the summer and early fall of 1959, winds switched to down-canyon in the afternoon on about a quarter of the days. From the surface records and a few double-theodolite and airplane observations, a diagrammatic model of this phenomenon has been constructed. The stability of the lower atmosphere along the coast was closely related to the occurrence of down-canyon winds in the area studied. The possibility of making short-range predictions exists by using this relationship along with other considerations.

(196) 1961. Topometeorology--the local scale. Amer. Met. Soc. Bul. 42(8):590.

Proposes the use of the term "topometeorology" for the study of atmospheric processes and motions having a scale between those of micro- and mesometeorology.

SCHROEDER, MARK J., and COUNTRYMAN, C. M.

(197) 1957. Fire-weather survey can aid prescribed burning. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Tech. Paper 21, 10 pp., illus.

Reports on a short-term fire-weather survey conducted on Iron Mountain prescribed burn, Lassen National Forest, in 1956.

SCHROEDER, MARK J., and COUNTRYMAN, C. M.
(198) 1960. Exploratory fireclimate surveys on prescribed burns. Monthly Weather Rev. 88(4):123-124.

Describes techniques used on four short-term fireclimate surveys and relates some observations, including an increase in wind speed blowing out the lee side of the fire, effects of the broad-scale weather on local patterns, down-canyon afternoon winds in east-facing canyons, and temperature observations and topographic effects on the lee side of a ridge.

SHOW, S. B., ABELL, C. A., DEERING, R. L., and HANSON, P. D.
(199) 1941. A planning basis for adequate fire control on the southern California National Forests. U.S. Forest Serv. Fire Control Notes 5(1):1-59, illus.

Analysis of 3035 fires on the four National Forests of southern California from 1922 to 1939 shows that man-caused fires in the flash-fuel and brush zones presented the dominant fire problem. Control of the fire during the first burning period was found to be important in reducing the total area burned to an acceptable maximum. Fast initial attack, with travel-control time not exceeding 15 minutes in the flash-fuel and brush zones, is necessary. Three-man initial attack crews for flash-fuel zones and five-man crews for brush zones are most efficient. Changes in travel time or crew size must be made for bad fire days. A full road system is needed to bring all risk areas within the scope of rapid, mechanized attack.

SHOW, S. B., and KOTOK, E. I.
(200) 1923. The occurrence of lightning storms in relation to forest fires in California. Monthly Weather Rev. 51(4):175-180, illus.

Ten years of records indicate the seasonal distribution of lightning fires, the number of fires per storm, the zones of lightning fire, the regions of heavy storm intensity, and the physical characteristics of lightning fires that affect fire control.

(201) 1923. Forest fires in California, 1911-1920; an analytical study. U.S. Dept. Agr. Cir. 243, 80 pp., illus.

Describes main factors--physical and human--in the problem of protection against forest fires. Examines various theories of protection. Analyzes variations in fires from diverse causes and the effect of these variations on means of control. Traces seasonal fluctuations in the intensity of fires due to climatic changes. Points out certain weaknesses traceable to flaws in organizations or to personnel weaknesses.

SHOW, S. B., and KOTOK, E. I.

(202) 1924. The role of fire in the California pine forests. U.S. Dept. Agr. Bul. 1294, 80 pp., illus.

Describes various forms of damage, both immediate and secondary; estimates the seriousness of each form of injury and its direct cost; surveys the effect of such losses on the future timber supply and on the problem of forest management; and includes a study of a "light-burning" experiment and some possible beneficial uses of fire apart from light burning. Attempts to present a workable theory of fire protection in relation to forest policy.

(203) 1925. Fire and the forest. (California pine region.) U.S. Dept. Agr. Cir. 358, 20 pp., illus.

Describes the immediate and secondary damage done to the forest by fire. Examines the successive deterioration of the forest from the first fire scar to the open forest to the brush field to the eroded soil. Covers "light-burning," fire and management, and fire exclusion for forest restoration.

(204) 1925. Weather conditions and forest fires in California. U.S. Dept. Agr. Cir. 354, 24 pp., illus.

Relates the relation between weather and forest fires using relative humidity, evaporation, wind velocity, and combinations of these three factors as the principle indicators of extreme fire weather.

(205) 1929. Cover type and fire control in the National Forests of northern California. U.S. Dept. Agr. Bul. 1495, 35 pp., illus.

Distinguishes the occurrence and behavior of fire in the major cover types as a basis of fire control, by means of average figures derived for each of the major types, showing length of season, prevalence of fires, rapidity of spread, and difficulty of control. Does not lead to a mathematical expression of the differences between types nor of the corresponding changes needed in fire control, but does include indications that are vital in the perfecting of the protection organization.

Points to the cover types in which protective work must be increased to preserve forest values and suggests certain means for reaching this end.

(206) 1930. The determination of hour control for adequate fire protection in the major cover types of the California pine region. U.S. Dept. Agr. Tech. Bul. 209, 46 pp., illus.

Presents the problem of the speed of attack needed to hold burned acreage to the accepted minimum. "Hour control" is the total time elapsing from the start of the fire until the first suppression forces start work. The hour-control problem is considered solely in the light of its relationship to the nine major cover types in the California pine region.

SHOW, S. B., and KOTOK, E. I.
(207) 1937. Principles of forest-fire detection on the National Forests of northern California. U.S. Dept. Agr. Tech. Bul. 574, 32 pp., illus.

Analyzes the fire-detection problem and concludes that the early lookouts did not cover the areas of intense risk adequately, and that detection methods other than continuous service lookouts were not desirable. Supplementary detection methods could be used in high risk unseen areas. The most economical and effective coverage is obtained only through planning the detection system as a whole for major protection units.

SHOW, S. B., KOTOK, E. I., GOWEN, G. M., and others.
(208) 1937. Planning, constructing, and operating forest-fire lookout systems in California. U.S. Dept. Agr. Cir. 449, 56 pp., illus.

The objective of the fire-detection system described is to see at a distance of less than 15 miles, the starting point of every fire, rather than every acre. This objective was accomplished in as far as practical, by the use of seen-area and fire occurrence maps in planning the detection system.

SMITH, HARVEY H., and BURKE, JOHN P.
(209) 1952. Keep you ax handle tight. U.S. Forest Serv. Fire Control Notes 13(3):4-6.

Suggests buying ax heads and handles separately rather than as a factory set, and using a soft wood wedge to tighten handles. Hard wood and metal wedges crush the fiber of handles. The ax head becomes loose when the handle dries and shrinks.

TAUXE, B. J., and STOKER, R. L.
(210) 1951. Analytical studies in the suppression of wood fires. Amer. Soc. Mech. Engin. Trans. 73(7):1005-1020, illus.

Presents results of two analytical studies. The first study concerns the instantaneous interfacial temperatures that occur when a drop of water hits the hot surface of a burning piece of wood. It shows that normally the drop will not instantaneously vaporize or bounce off and that initially the relative wetting abilities of the suppressing agents may be important. The second study uses an electrical analogue computer to investigate the simulated thermal behavior of wood as it burns and as it is extinguished by surface cooling, by penetration cooling, and by oxygen dilution.

WAKLEE, FLOYD W., SHIELDS, H., and WILSON, C. C.

(211) 1957. The helicopter--a new member of the hose-lay team. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Res. Note 129, 11 pp., illus.

Summarizes results of 1957 hose-lay tests conducted over a 2-mile course by the California Division of Forestry, the Arcadia Equipment Development Center, and the Experiment Station. Demonstrates the role helicopter can play in a long hose-lay operation.

(212) 1958. The helicopter joins the hose-lay team. U.S. Forest Serv. Fire Control Notes 91(2):88-90, illus.

Describes how helicopters can supplement ground equipment in laying fire hose over different types of vegetation.

WILSON, C. C.

(213) 1957. A bird's eye view of forest fire research in the United States. Pulp and Paper Mag. 58(18):196-197.

Brief summary of prevention, suppression, and basic studies.

(214) 1957. Helitack. Pulp and Paper Mag. 1957:384-388.

Reports helicopter use on forest fires in Canada and United States since 1946.

(215) 1957. New techniques in forestry. Chemicals retard forest fires. No. Calif. Sec. Soc. Amer. Foresters Proc. 1956:22-24.

A preliminary report on use of sodium calcium borate on forest fires.

(216) 1958. Control of aircraft on forest fires. U.S. Forest Serv. Fire Control Notes 19(2):35-39.

Describes functions necessary for safely controlling a complex operation of aircraft on forest fires and suggests one way of fitting these functions into the over-all fire control organization.

(217) 1960. Are land managers making the best use of chemicals for forest fire fighting? Western Fire Res. Com. Proc. 6 pp.

Defines "fire retardants" and "fire suppressants" and outlines their development since 1821. Concludes that wildland managers are not making the best use of firefighting chemicals. Recommends the use of "wet water" for mop-up operations in deep duff and

and punky logs, and the use of new thick water suppressants and fire retardants in ground tankers. Cautions against placing complete reliance on laboratory tests of fire retardants and suppressants.

WILSON, C. C.
(218) 1960. Wildland fire protection in California--does it have a future? The Fireman's Grapevine 36(3):6-8.

Considers California's immediate and future fire problems, what has been done in the past, and what research hopes to achieve in the future in alleviating these problems.

UNPUBLISHED REPORTS

These are progress reports and papers that were never reproduced in large numbers.

ABELL, C. A.
(219) 1941. Progress report on experimental testing of cooperator forest fire detection on the Angeles National Forest in Los Angeles County. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 16 pp., illus.

A fire detection problem on the Angeles National Forest was indicated when it was found that only 10 percent of man-caused fires were reported by lookout observers and a similar small number of first reports were made by lookouts in Los Angeles County. Individual fire reports showed, however, that 65 percent of man-caused fires were discovered within 15 minutes of origin. To check this figure smoke candles were set off at selected locations in Los Angeles County and provisions were made for recording data where calls were expected. The results indicated remarkable performance of the public as detectors; 10 test smokes were reported within 15 minutes, and 81 percent of all reports were within the same time period. Only one fire was reported first by a lookout observer.

BRUCE, H. D.
(220) 1938. Instructions in the use of chemicals for sterilizing soil. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 7 pp.

Describes the use and effects of three arsenic compounds for removing vegetation.

BUCK, CHARLES C.
(221) 1938. Progress report on the measurement of volume of fuel on brush milacre plots on the Shasta Experimental Forest. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 28 pp., illus.

Nine milacre plots in different stands of brush were studied to determine their rate of fire spread characteristics, to measure the total and relative quantities and distribution of kinds of fuel present, and to provide the quantitative measure of the fuel factor needed in current rate of spread studies. All material from each plot was removed, segregated into different species, kinds, and size classes, weighed, and the dry weight of each fuel class determined. The data for each plot were tabulated separately, and a summary for all plots prepared.

BUCK, CHARLES C.

(222) 1938. Progress report on the rate of spread studies in the northern California brush type. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 19 pp., illus.

The objective of test fires in brush is to determine the influence of wind and fuel moisture content on the rate of spread. Two distinct stages were noted in the spread of all the fires. During the first stage, before crowning, behavior is largely governed by local distribution of fuel about the starting point and is highly inconsistent. In the second stage, after a fire has become established, it reacts in the expected manner to changes in wind and fuel moisture.

(223) 1938. Progress report on resistance to control study. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 28 pp., illus.

Provides preliminary information concerning the amount of fire line which can be built per man hour in the various cover types of northern California. Lines were constructed in five distinct types of fuel cover by a 3-man crew. Tools were limited to axes, shovels, and McLeod tools. Work was carried on in a manner to eliminate, insofar as possible, the fatigue factor. Air temperature, humidity, and water used were recorded as well as the amount of line constructed, percentage of time each tool was used, and other pertinent line construction data. Summary tables for each cover type and a final summary for all types are given.

(224) 1938. Progress report on the variations in moisture content of surface needles in ponderosa pine litter. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 27 pp., illus.

Data were collected to indicate the typical variations to be expected in stands in the area studied. The data also indicated that the influence of such factors as sun, shade, time, dew, and perhaps soil and lower duff moisture content must be taken into consideration in correlating fuel moisture content with weather conditions and such moisture indicators as used in fire danger rating work.

BUCK, CHARLES C.
(225) 1939. Progress report on variations in the moisture content of green brush foliage on the Shasta Experimental Forest during 1938. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 35 pp., illus.

Presents results of observations and measurements of moisture and volume variations in the green foliage of manzanita and snowbrush during 1938. The average green foliage moisture content of both species observed varied widely during the fire season. Sufficient observations were made so that reliable indices of the seasonal stages of this varying moisture content could probably be set up for field use. Similar diurnal moisture content variations of from 4 to 8 percent were found for both species, the lowest moisture content occurring about 2 p.m. About twice as many leaves will be on the branches at the peak of the growing season as in the spring, fall, and winter months for both species.

BUCK, CHARLES C., BRUCE, H. D., ABELL, C. A., and FONS, W. L.
(226) 1941. A forest fire protection problem analysis for California. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 143 pp., illus.

Seventy-seven generalized fire protection problems of adminstrative importance are arranged under the activities of prevention, presuppression, suppression, effects, and economics. Each problem is rated "high," "medium," or "low" as to its administrative importance by a group of qualified forest managers.

COUNTRYMAN, C. M.
(227) 1960. Fire climate patterns and fire behavior. Paper presented at West. States Sect. The Combustion Inst., Palo Alto, Calif. 12 pp.

Air flow patterns in small, sharply defined canyons can be extremely complex. Observations showed that wind pattern in a mountian canyon for short intervals may be considerably different from the average over a period of an hour or more. Fires respond quickly to wind, and fire behavior may be expected to be more closely associated with the short-period patterns than with the long-term average. The integrated effect of all environment factors control fire behavior, and not necessarily the level of any one or two factors.

FONS, W. L.
(228) 1937. Storage and catchment of rainfall for water supply in fire suppression. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 18 pp., illus.

Three years' experimentation with various kinds of materials and types of rainfall catchments show reinforced concrete as the most promising material used in catchments and storage tanks. A cylindrical storage tank 11 feet in diameter and 11 feet tall is recommended to give the calculated required capacity and most economical cost per gallon. The size of the catchment area depends upon the annual rainfall and number of tanks it is to serve.

FONS, W. L.

(229) 1938. Progress report of wind studies on the Shasta Experimental Forest. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 65 pp., illus.

Describes wind measuring instruments, their calibrations, and uses, Includes studies of variation of wind velocity from place to place in a pine stand, horizontal wind velocity in relation to height above the ground surface, and diurnal variation of the velocity of prevailing winds.

(230) 1940. Analytical considerations of model forest fires. (Unpublished master's thesis. Copy on file Dept. Mech. Engin., Univ. Calif., Berkeley, Calif.)

By the application of principles of heat transfer a theoretical analysis is made of open-air combustion in model fuel beds and equations are derived relating the rate of spread of free flame with physical characteristics of the fuel particle and fuel bed. Different equations are derived for fires with and without wind. An equation is presented for the equivalent specific heat of a fuel as a function of its absorbed moisture and temperature. By application of equations derived from data of earlier test fires the effect of wind velocity on the spread of fires is shown and a method of evaluating experimentally the effective size in mixtures of fuel is given.

(231) 1940. Forest fuels progress report 6. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 47 pp., illus.

Covers the progress made in establishing the effect of compactness in ponderosa pine needle litter on the spread of surface fires with varying wind velocity and moisture content.

Test fires were burned in prepared beds of ponderosa pine needles in a low velocity wind tunnel.

(232) 1943. Progress report on seasonal variation in moisture content of chaparral foliage on the San Dimas Experimental Forest during 1942. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 9 pp., illus.

Provides information on seasonal variations in moisture content in the important chaparral species of southern California. The information is to be used in adjusting measured values of indicator stick moisture content in rating fire danger. Five species of brush that comprise about 80 percent of the forest cover below the 4,500-foot elevation were studied. Observations were made on both north and south slopes. Seasonal trends in the leaf moisture content of each species were established. Moisture content comparable to that prevailing in the northern California brush fields were found to prevail during the spring growing season. During late summer, however, leaf moisture well below 50 percent is not uncommon.

FONS, W. L., and BLANCHARD, R. K.
(233) 1938. Progress report on forest fuels. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 42 pp., illus.

Describes the influence on the rate of fire spread of the volume of voids per unit surface area of the fuel. Preliminary laboratory experiments showed that this factor correlates well with rate of spread with no wind and constant moisture conditions. These experiments were extended to the field and continued in the laboratory during 1936 and 1937. It was found that for pine needle fuel the effect of moisture content on rate of spread decreases as the ratio of voids per unit surface area decreases. The studies indicate that for zero wind the ratio of volume of voids to surface area of the fuel and moisture content explain the variation of rate of spread in needle litter fuels.

FONS, W. L., and STROMBERG, R. W.
(234) 1941. Fire ignition progress report 1. U.S. Forest Serv. Calif. Forest & Range Expt. Sta. 23 pp., illus.

The results of experiments clearly indicate that probability of ignition is complicated by the effect of atmospheric conditions on the firebrand as well as on the fuel. Results of 114 tests using half cigarettes as firebrands (20 cigarettes per test) dropped on Douglas-fir punk showed that the probability of a lighted cigarette remaining a firebrand decreases with increasing wind velocity. The probability of ignition by a cigarette that remains a firebrand increases with increased wind velocity.

PIRSKO, ARTHUR R.
(235) 1960. A report on development of new fire danger rating indexes. Paper presented at California-Nevada Fire Res. Council, Reno, Nev. 6 pp.

Explains the new ignition index and new fire load index. Samples six areas in California to show the fire weather pattern of the 1960 fire season. Indicates future research needs in fire danger rating.

(236) 1961. Wildland fire danger rating--multi-indexes for multiple fire use. Paper presented at South. Sect. Central Sierra Forest Fire Conf., Bass Lake, Calif. 11 pp.

Explains the use of new indexes in wildland fire danger rating to land managers. Shows the specific uses for indexes in dispatching, use of air tankers, hazard reduction, fire prevention, and spotting potential. Possible administrative uses for the indexes include controls on fire or burning permits.

Wilson, Carl C., and Nilsson, Jerry R.
1962. Forest fire research in California, an annotated bibliography, 1923-1961. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Misc. Paper 75, 48 pp.

The 236 items include all the written material on U.S. Forest Service forest fire research in California through 1961.

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MISCELLANEOUS PAPER No. 76
1962

SOILS of the San Dimas Experimental Forest

James M. Crawford, Jr.

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ACKNOWLEDGMENT

The San Dimas Experimental Forest is maintained by the Forest Service, U.S. Department of Agriculture, in cooperation with the California Division of Forestry. Since 1947 this area has been a joint research project with the California Division of Forestry, which participates in program planning and provides financial support. Other long-term cooperators are the Los Angeles County Flood Control District, the Los Angeles County Fire Department, and the University of California, which provides staff or other support, or use research facilities at the experimental forest.

Special recognition is due these agencies and the California Department of Water Resources for assistance with emergency rehabilitation work after a wildfire in July 1960. Their cooperation made it possible to restore experimental facilities and start emergency research on methods of managing chaparral watersheds for more effective control of fires, floods and erosion, and water yield. A part of this research program was an intensive soils survey of the San Dimas Experimental Forest.

SOILS OF THE SAN DIMAS EXPERIMENTAL FOREST

By
James M. Crawford, Jr., Research Forester

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U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE

PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION

Berkeley, California

SOILS OF THE SAN DIMAS EXPERIMENTAL FOREST

By

James M. Crawford, Jr.

Research Forester

The soils of the San Dimas Experimental Forest were mapped in September and October after a wildfire on July 20, 1960, burned 15,000 acres of the 17,000-acre forest. This experimental area lies on the foothills of the San Gabriel Mountains about 30 miles northeast of Los Angeles. Elevation ranges from 1,300 feet in Big Dalton Canyon in the southwest to almost 5,600 feet in the northeast. The San Dimas Experimental Forest has a Mediterranean climate: cool winters when most of the annual rainfall occurs and hot, dry summers. Snow sometimes falls at high elevations, but is infrequent and melts rapidly. Average precipitation at the Tanbark Flat headquarters (2,700 feet) is 27 inches. Average temperature at Tanbark for the coldest month (January) is 46.6°F. The minimum temperature recorded there was 18°F.; the maximum was 108.5°F.; and the annual mean temperature, 57.7°F.

Rocks within the experimental forest belong to an igneous-metamorphic complex. In most of the area, they occur as small intrusions and inclusions which are intricately associated with other small bodies. Most rocks date to pre-Cambrian or Paleozoic eras. Diorites, schists, gneisses, granites, and granodiorites are the most common. Dikes are also common and generally composed of pegmatite, aplite, silexite, dacite, and lamprophyre. Immediately south of Johnstone Peak and west of San Dimas Dam lie two volcanic areas of andesite and basalt.

Only the southernmost part of the experimental forest has relatively gentle slopes; most of the area has very steep slopes. The minutely dissected area around Tanbark Flat is generally of the same geological composition as the rest of the forest, but it shows a different aspect from the deep, wide canyons common to the west and the south. Bean (1944)[1] contends that the Tanbark area developed during a period of diastrophic quiet after the San Gabriels had already been elevated considerably. After this quiet period, further uplift rejuvenated the mountain range. The streams began to cut anew, working headward from the edge of the mountains. This down-cutting is still active.

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[1] Bean, Robert T. Geology of watersheds, V, VII, and Lower VI, San Dimas Experimental Forest, Progress Report. p. 3, 1944. (Unpublished report on file Pacific SW. Forest & Range Expt. Sta., U.S. Forest Serv., Berkeley, Calif.)

Shrubs dominate the forest vegetation. Tree forms can develop along stream channels and at the higher elevations in the eastern part on northerly slopes. Hardwoods predominate, although one conifer, *Pseudotsuga macrocarpa*, is fairly common, especially on steep colluvial slopes. *Pinus ponderosa* grows at Browns Flat. Hardwoods line the bottoms of most larger canyons.

Common hardwood species include:

Alnus rhombifolia
Platanus occidentalis
Quercus chrysolepis
Quercus agrifolia
Umbellularia californica

Common shrubs include:

Adenostoma fasciculatum
Arctostaphylos glauca
Ceanothus leucodermis
Cercocarpus betuloides
Eriodictyon trichocalyx
Garrya fremontii
Haplopappus squarrosus
Lonicera subspicata
Nicotiana glauca
Photinia arbutifolia
Prunus illicifolia
Quercus dumosa
Quercus wislizenii
Rhus diversiloba
Rhus laurina
Rhus ovata
Salvia mellifera
Yucca whipplei

MAPPING PROCEDURES

Areas were delineated on aerial photographs according to slope classes to a minimum of 2-1/2 acres. The scale of the aerial photographs was about 1:10,000.

Percent slope	Slope class
0-39	1
40-54	2
55-69	3
70-	4

Within each class soils were mapped as to series and vertical depth. Seven tentative soil series were mapped, and each series is described in this report. Soil depths fell into one of five classes:

Soil depths, inches	Depth class
0-11	1
12-23	2
24-35	3
36-47	4
48-	5

The depth class shown in a symbol means the average depth within an area. Depths are extremely variable within short distances, but soil depth is generally correlated to slope and aspect. As a rule, the steeper the slope, the shallower the soil. North-facing slopes generally have deeper soils than south-facing slopes. Soils derived from gneiss are deeper than those found on diorites and schists.

Slope class 4 soils on parent material other than gneiss are generally less than 12 inches deep, slope class 3 soils usually are less than 24 inches deep, and depths of soils on slope classes 1 and 2 usually exceed 24 inches.

Four rockiness classes were established:

Rockiness	Rockiness class
Less than 10 percent surface rocks greater than 3 inches in diameter (excluding large rock outcrops, which have their own symbol).	No symbol
Greater than 10 percent surface rocks greater than 3 inches in diameter, but less than 10 percent surface rocks greater than 24 inches in diameter.	R1
10 to 50 percent surface rocks greater than 24 inches in diameter.	R2
Greater than 50 percent surface rocks greater than 3 inches in diameter	R3

Numerous rock outcrops occur in R1 areas. These scattered outcrops have been ignored in determining the rockiness classification for a particular area. Rock outcrops of less than 2-1/2 acres have been given the symbol "V". Most of the forest has R1 rockiness classification; a significant part has less than 10 percent rockiness. Soils developed from pure gneiss have no surface rockiness. An extensive area of rock-free soil is found northwest of the upper East Fork of San Dimas Canyon. The total acreage in the R2 and R3 classes is small.

SOIL SYMBOLS

The soils were mapped according to standard soil series criteria. Each series has been tentatively designated by a capital letter. Depth class, slope class, and amount of surface rockiness are also included in each description, which is represented by a fractional symbol. An example of a typical symbol is:

$$\frac{\text{Ac}}{\text{2R1-4}}$$

In the above example the soil series is "A." The small "c" shows that the soil is colluvial; a small "a" indicates an alluvial soil. The number "2" means that the average depth of the soil is from 12 to 28 inches. R1 indicates that the soil has more than 10 percent of surface rocks over 3 inches in diameter, but less than 10 percent rocks over 24 inches in diameter. The number "4" shows that the average slope within the type is greater than 70 percent.

SOIL SERIES

"A" SERIES[2]

Excessively-drained, shallow, and coarse-textured, the "A" soils are derived from diorites, granodiorites, schists, and gneiss. These soils are typical of the entire San Dimas area up to about 4,500 feet elevation. Above 4,500 feet they are replaced by the "G" soils. The "A" soils are common on steep slopes, especially those over 40 percent. On ridges, benches, and areas of gentle slope the "A" soils are replaced by the "B" or "C" soils.

The "A" soils range from neutral at the surface to slightly acid at about 2 feet below. These soils are usually gravelly and stony throughout the profile. The boundary between the soil and the underlying decomposed parent material is very gradual; the soil is often undistinguishable from the parent material.

These soils have weak, angular, blocky structure. Their consistency is loose when dry, and loose to very friable when moist. Depths are mostly less than 24 inches, measured vertically.

Soil profile.--

1. 0-5 inches	Pale brown (10YR6/3 dry, 10YR4/3 moist) gravelly, sandy loam; weak to moderate, medium, angular, blocky structure; soft when dry to very friable when moist; very slightly acid to neutral; 1 to 6 inches thick; gradual, wavy lower boundary.
2. 6-11 inches	Pale brown (10YR6/3 dry, 10YR4/3 moist) gravelly, loamy sand; weak to moderate, fine, angular, blocky structure; loose when dry to very friable when moist; very slightly acid; 5 to 10 inches thick; gradual, irregular lower boundary.

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[2] These soils are classified according to accepted soil series standards. No attempt will be made to correlate these soils as part of the National System for the time being.

3. 12-16 inches	Light yellowish brown (10YR6/4 dry, 10YR4/3 moist) sandy gravel; weak, fine, angular, blocky to single-grain structure; loose when dry to loose when moist; slightly acid; 5-10 inches thick; diffuse lower boundary.
4. 17- inches	Heavily weathered igneous and metamorphic rocks, mostly gneiss, schists, diorites, and granodiorites; variations of rock type occurring within short distances, sometimes within a few feet.

Range in characteristics.--The surface color (dry) ranges from pale brown to brown. The subsoil color (dry) ranges from light yellowish brown to yellowish brown. Subsoil texture ranges from a gravelly, sandy loam to a gravelly sand. The soils are typically gravelly, and become increasingly rocky with depth. Typically more than 10 percent of the surface is covered by rocks over 3 inches in diameter. Soil depth is variable within short distances. Shallow and very shallow depth phases predominate. Distinct soil horizons may often be lacking.

Topography.--Slopes vary from steep to extremely steep. Very steep slopes are by far the most common. The "A" soils generally occur below 4,500 feet elevation.

Drainage and permeability.--The soils are excessively drained. The underlying decomposed rock can absorb large amounts of water.

Vegetation.--Chaparral. *Rhus ovata*, *Quercus dumosa*, *Quercus wislizenii*, *Adenostoma fasciculatum*, *Yucca whipplei* *Eriogonum* sp., *Salvia mellifera*, *Eriodictyon trichocalyx*, and *Photinia arbutifolia* are the most common shrubs.

Use.--Watershed protection; browse and cover for wildlife.

Distribution.--San Gabriel Mountains of southern California.

Type location.--Sec. 3, T1N, R9W. San Bernardino Meridian. Head of Monroe Canyon, 350 feet below ridge near trail.

Remarks.--This soil is probably common throughout mountainous areas of southern California with similar vegetation and geology.

"B" SERIES[3]

The "B" soils are well-drained, moderately coarse-textured, fairly deep soils occurring usually on gneiss. They commonly occur on relatively gentle, north-facing slopes. In areas where gneiss is extensive, "B" soil occurs on all aspects, although it is shallower on south-facing, extremely steep slopes. "B" soil is similar to "A", but is deeper, shows more development, has better and stronger structure, and is less rocky. "A" occurs on steeper slopes and usually on parent materials having a higher percentage of quartz. In some areas of "B", soil development approaches a clay loam. Here the soils somewhat resemble "C" soils, but "C" contains a larger amount of small quartz grains and is typically redder than "B".

The "B" soils range from very slightly acid at the surface to slightly acid at the top of the decomposed underlying rock. Very little surface rockiness and very little stoniness within the profile are found in this series. Some areas of pure gneiss are entirely rock-free.

Often we found it extremely difficult to determine the depth of this soil because the decomposed parent material below is heavily weathered 10 to 15 feet deep or more. The "horizon" at these depths often resembles horizons near the surface, the only apparent difference often being the degree of cementation and aggregation of the minerals composing the rock. The material near the surface is loose or only slightly aggregated, whereas several feet deeper, the material is more firmly cemented. Slight pressure however, will reduce this decomposed rock to its mineral fragments. This deeper material to all appearances is almost identical to that nearer the surface. Vegetation appears to grow equally well in areas where the more firmly cemented material outcrops at the surface and in areas of loose soil material.

"B" soil has a moderate to strong, fine to medium, angular, blocky structure. Its consistency is slightly hard when dry to very friable when moist. Depths usually exceed 3 feet, measured vertically.

This soil is well drained and has a high water holding capacity. Erosion is not a serious problem.

Soil profile.--

1.	0-4 inches	Light yellowish brown (10YR6/4 dry, 10YR3/3 moist) silty, sandy loam; moderate to strong, medium, angular, blocky structure; slightly hard when dry to very friable when moist; very slightly acid; 2 to 6 inches thick; gradual, wavy lower boundary.

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[3] Tentative series, not correlated.

2.	5-28 inches	Very pale brown or yellow to yellowish brown (10YR7/5 dry, 10YR5/6 moist) silty, sandy, loam; moderate to strong, fine, angular, blocky structure; slightly hard when dry to very friable when moist; slightly acid; 6 inches to 4 or 5 feet thick; diffuse lower boundary.
3.	29- inches	Heavily weathered gneiss, sometimes with an admixture of diorites and schists.

Range in characteristics.--The surface color (dry) ranges from light yellowish brown to brown, and the subsoil color (dry) from yellowish brown and very pale brown to a somewhat reddish brown. The subsoil texture is usually a sandy loam or a silty, sandy loam, sometimes approaching a clay loam. The "B" soils are typically non-rocky, non-stony deep soils. In many areas dikes, often quartzitic, permeate the gneiss. Soils with more than 10 percent surface rockiness (rocks more than 3 inches in diameter) can often be found there. Soil depth is quite variable over short distances, and ranges from 3 to 5 feet and more.

Topography.--Slope varies from non-steep to extremely steep, but is typically steep (30-50 percent). The "B" soils are usually found below 4,500 feet elevation.

Drainage and permeability.--The soils are well-drained, and erosion is less severe than on the "A" soils. Water holding capacity of the "B" soils is greater than that of "A".

Vegetation.--Chaparral. *Quercus dumosa*, *Adenostoma fasciculatum*, *Arctostaphylos glauca*, *Salvia mellifera*, *Rhus ovata*, and *Yucca whipplei* are the most common shrubs.

Use.--Watershed protection; browse and cover for wildlife.

Distribution.--San Gabriel Mountains of southern California.

Type location.--Sec. 1, T1N, R9W, San Bernardino Meridian, 100 feet west of Little Bell Dams road, 600 feet west of junction with Dalton Road.

Remarks.--This soil may be expected throughout southern California mountain areas under conditions similar to the type location.

"C" SERIES[4]

The "C" soils are moderately fine-textured and well-drained. They developed mainly from granodiorites and quartz diorites and have many quartz grains. They occur most commonly on narrow ridges, but have also been found at lower elevations on northerly, gentle to steep slopes. The occurrence of "C" soil is probably determined by a combination of minerals of high iron content and quartz in the parent material. Also, a certain amount of soil stability is needed to permit clay development. Soil stability and moisture retention perhaps explain why there is a tendency toward finer textured soils on the narrow ridges although these soils may be extremely shallow. A coating of reddish colloidal clay may be deposited as a thin film within the cracks and crevices of the decomposed rock. A first glance, this material looks like gravel and cobbles of pure clay, but closer examination reveals the fine deposit of clay on the surface of the decomposed rock. Occasionally the rock seems to be saturated with the clay. Some areas show good development of clay in the soil as well as the clay film deposits. The occurrence of "C" soil is erratic, and seldom in areas of mappable size. Many broad flat ridges have "A" or "B" soils, where one might expect the "C" soils to have developed.

The "C" soils range from neutral at the surface to medium and strongly acid in the subsoil. On many of the shallower ridges the subsoil is slightly acid. The soils may be stony or non-stony. Their structure is strong, fine, angular, and blocky. Their consistency is slightly hard when dry near the surface and very hard when dry in the subsoil. When moist, the soil is friable throughout the profile. Depths are usually greater than 24 inches, measured vertically, but may be only a few inches on narrow ridges.

In its less reddish phases "C" soil closely resembles the Auberry series of the Sierra foothills.

Soil profile.--

1.	0-6 inches	Light brown (7.5YR6/4 dry, 7.5YR5/6 moist) sandy loam; strong, fine, angular, blocky structure; slightly hard when dry to friable when moist; very slightly acid to neutral; 2 to 6 inches thick; clear, abrupt lower boundary.
2.	7-20 inches	Light brown (7.5YR6/4 dry, 7.5YR4/4 moist) sandy clay loam; strong, medium, angular, blocky structure; hard when dry to friable when moist; slightly acid to very slightly acid; 6 to 20 inches thick; gradual, irregular lower boundary.

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[4] Tentative series, not correlated.

3. 21-48 inches	Reddish yellow to light brown (7.5YR7/6 to 7.5YR6/4 dry, 7/5YR4/4 moist) gravelly, sandy clay loam; strong, medium, angular, blocky structure; very hard when dry to friable when moist; strongly acid to medium acid; 6 to 24 inches thick; diffuse lower boundary.
4. 49- inches	Decomposed quartz-diorite, becoming less weathered and more solid with depth.

Range in characteristics.--The color varies widely, ranging from reddish and reddish yellow to light brown, and may occasionally be mottled. Partially weathered feldspars sometimes give the subsoil a whitish, mottled appearance. Typically a clay loam; subsoil texture may or may not be stony. Subsoils are usually considerably more acid than the surface horizon. Depths range from a few inches to 4 feet.

Topography.--Slopes are usually flat to gentle. "C" soil is seldom found on very steep slopes. It generally occurs below 4,000 feet.

Drainage and permeability.--The soils are well-drained, yet have a high waterholding capacity because of the clay development within the subsoil.

Vegetation.--Chaparral. *Photinia arbutifolia*, *Cercocarpus betuloides*, *Quercus dumosa*, *Quercus wislizenii*, *Garrya fremontii*, *Haplopappus* sp., *Solanum* sp., *Lonicera* sp., *Rhus laurina*, and *Rhus ovata* are some of the most common shrubs.

Use.--Watershed protection; browse and cover for wildlife.

Distribution.--Lower elevations and foothills of the San Gabriel Mountains of southern California.

Type location.--Sec. 19, T1N, R8W, San Bernardino Meridian, 1/4 mile west of watertank along Sunset Truck Trail.

Remarks.--The apparently limited occurrence of "C" soil will probably prevent its serious consideration in future land management planning. Its occurrence on ridges indicates the soil type that could possibly develop elsewhere if the slopes were gentler and water or gravity did not remove the soil almost as fast as it is formed. The deeper phases of "C" are among the better soils of the San Dimas area.

"D" SERIES[5]

The "D" soils are moderately well developed, fine-textured, somewhat poorly drained soils developed on calcareous tufa. They are commonly associated with springs. Whether calcareous tufa develops around all springs is unknown. Bean, in reporting on the geology of the Big Dalton and Little Dalton watersheds, wrote: "Recent deposits of calcareous tufa, some of which might be mistaken for bed-rock, occur in the canyons in many places. These cover the rocks at many waterfalls and at certain springs. In many places the gravel in stream bottoms, which are largely dry in the summer, is cemented into a kind of conglomerate by tufa. This 'conglomerate' ordinarily remains where formed in the stream-bed, but in a few places, pieces of it have been broken off and have been carried away as part of the stream gravel."[6]

In the soil survey of the San Dimas Experimental Forest, we found only one area with soils developed from this calcareous tufa. Near the head of Volfe Canyon, "D" soil occurs spottily with the common "A" soil. Nothing in the character of the topography nor in the vegetation appears to indicate the underlying calcareous soil. The area at the time of mapping had recently burned. Shrub species, as determined from sprouts, were the same as on adjacent soils derived from the diorites, except that in some areas, only Rhus ovata and Prunus illicifolia were growing. It is possible that other species which might indicate the calcareous nature of the soil did exist but were destroyed by the fire of July 20, 1960.

The "D" soils range from neutral near the surface to alkaline from 6 or 8 inches to the hard whitish tufa at about 24 inches. The structure is strong, fine, angular, blocky at the surface to almost massive below 16 to 18 inches. The consistency is soft when dry near the surface and slightly hard when dry in the subsoil. When moist, "D" is friable to firm throughout the profile. Depths are usually over 2 feet, measured vertically. In some places the calcareous tufa is exposed at the surface.

Soil profile.--

1. 0-6 inches	Light yellowish brown (10YR6/4 dry, 10YR 5/6 moist) gravelly, sandy loam; strong, fine, angular, blocky structure; soft when dry to friable when moist; neutral; 1 to 6 inches thick; gradual, wavy lower boundary.
2. 7-16 inches	A mixture of grayish brown, brownish yellow, pale yellow (10YR5/2 moist, 10YR6/8 moist, 2.5Y8/4 moist) heavy clay loam; strong, fine,

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[5] Tentative series, not correlated.

[6] Bean, Robert T. Geology of the Big Dalton and Little Dalton watersheds. p. 2, 1943. (Unpublished report on file Pacific SW. Forest & Range Expt. Sta., U.S. Forest Serv., Berkeley, Calif.)

2. (con.)	angular, blocky structure; slightly hard when dry to firm when moist; neutral to alkaline; 8 to 12 inches thick; clear, abrupt lower boundary.
3. 17-22 inches	A mixture of grayish brown, brownish yellow, pale yellow, and white (white the most common) (10YR5/2 moist, 10YR6/8 moist, 2.5Y8/2 moist) sandy clay loam; moderate, medium, angular, blocky to almost massive structure; slightly hard when dry to friable when moist, alkaline; 6 to 12 inches thick; gradual, irregular lower boundary.
4. 23- inches	Calcareous tufa, somewhat porous.

Range in characteristics.--From about 6 inches to the tufa, the soil series is a mixture of yellows, grays, whites, and a touch of red. The yellow and gray colors probably reflect the poor drainage which is typical of this soil. Texture ranges from a sandy loam near the surface to a heavy clay loam near the parent material. Not enough of this soil has been found to indicate a range of characteristics. It is of interest only as a curiosity.

Topography.--Slopes are gentle. The soil was found at about 3,000 feet near the head of Volfe Canyon, but it may be expected to occur at lower or even higher elevations where tufa is formed.

Drainage and permeability.--This soil is imperfectly to poorly drained. Moisture was present at the time of mapping in early fall. This moisture is attributed to springs and a high water table in this immediate vicinity.

Vegetation.--Chaparral. Rhus ovata and Prunus illicifolia are the most common species. Photinia arbutifolia and Adenostoma fasciculatum were also observed.

Use.--Watershed protection; cover and browse for wildlife.

Distribution.-- The distribution of this series is impossible to determine. The soil certainly is limited but can be expected to occur near the head of canyons, along stream courses, or where springs might be expected to occur throughout the foothills and middle elevations of the San Gabriel Mountains in southern California.

Type location.--Sec. 2, T1N, R9W, San Bernardino Meridian. Head of Volfe Canyon along trail, 0.2 miles northeast of burned cabin.

"E" SERIES[7]

The "E" soils are moderately coarse-textured to medium textured, well-drained, fairly deep soils, developed mostly from a heavily weathered schist. In places the parent material is gneissic; elsewhere it is somewhat andesitic or basaltic. "E" soil occurs in the higher foothills on fairly gentle to slightly steep slopes; it is commonly associated with "F" soil, which occurs on a purplish andesite. The "E" soils usually have more than 10 percent surface rockiness, but may be stony or non-stony. "E" soil somewhat resembles the deeper "A" soil, and closely resembles the Tyson soils on Franciscan sandstone in northwestern California.

The "E" soils rank among the better soils in the San Dimas area, being generally more than 3 or 4 feet deep. They often support good stands of hardwoods or tall dense brush.

Soil profile.--

1.	0-6 inches	Grayish brown (2.5Y5/2 dry, 10YR3/2 moist) sandy loam; strong, fine, angular, blocky structure; slightly hard when dry to very friable when moist; very slightly acid to neutral; 4 to 8 inches thick; abrupt, smooth lower boundary.
2.	7-20 inches	Pale brown (10YR6/3 dry, 10YR3/3 moist) sandy loam to sandy, clay loam; strong, medium, angular, blocky structure; hard when dry to very friable when moist; slightly acid; 1 to 2 feet thick; clear, wavy lower boundary.
3.	21-44 inches	Pale brown (10YR6/3 dry, 10YR3/3 moist) gravelly, sandy loam; strong, medium, angular, blocky structure; hard when dry to very friable when moist; slightly acid, 1-1/2 to 2 feet thick; diffuse lower boundary.
4.	45- inches	Heavily weathered schist; sometimes andesitic parent material.

Range in characteristics.--This soil is generally pale brown or grayish brown, with little color variation throughout the profile or between different profiles. Depths, on the whole, surpass 3 feet, although a number of areas are shallow and rocky. The soil is fairly free of stones in the profile, except in the shallow rockier phases. The pH, which is generally slightly acid, varies little.

Topography.--Slopes are almost flat or gentle to moderately steep, the deeper soils occurring on the gentler slopes. Elevations range from 2,000 to 3,500 feet.

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[7] Tentative series, not correlated.

Drainage and permeability.--The "E" soils are well-drained and have a fairly high water-holding capacity.

Vegetation.--Chaparral and hardwoods. Quercus agrifolia, Photinia arbutifolia, Rhus diversiloba, and Vicia sp. grow on the deeper phases. Eriogonum sp., Quercus dumosa, Salvia mellifera, Garrya fremontii and various annual grasses grow on the shallower phases.

Use.--Watershed protection; cover and browse for wildlife.

Distribution.--Foothills and medium elevations of San Gabriel Mountains in Los Angeles County.

Type location.--Sec. 23, T1N, R9W, San Bernardino Meridian, near intersection of Bluebird Truck Trail and road to Johnstone Lookout, about 500 feet from Lookout.

Remarks.--This soil would probably respond well to conversion to grass, but it is not extensive and hence may not be important in land management.

"F" SERIES[8]

The "F" soils are fine-textured to moderately fine-textured, deep soils developed from andesite. They occur in the lower foothils of the San Gabriel Mountains from 1,500 to 2,000 feet elevation. "F" soil is probably the best soil for conversion to grass within the entire San Dimas area. It occurs on flat and gentle to moderately steep slopes. The soil probably can support a dense cover of brush, trees, or grass. It seems very stable, although slipping may occur in some areas. Because of the deep soil and the high clay content, the "F" soils have a high water-holding capacity.

Ranging from very slightly acid near the surface to medium acid near the parent material, these soils generally are not stony or gravelly. The deeper phases show considerable clay development. In some areas there is a foot of dense clay, probably montmorillonite in the subsoil.

The "F" soils have strong, medium, subangular, blocky to strong, coarse, subangular blocky structure. Their consistency is soft when dry and friable when moist near the surface. The consistency in the subsoil varies from very hard to extremely hard when dry, and is firm when moist. Depths are commonly greater than 3 feet.

Soil profile.--

1.	0-5 inches	Dark grayish brown (10YR4/2 dry, 10YR3/2 moist) sandy clay loam; strong, medium, subangular, blocky structure; soft when dry to

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[8] Tentative series, not correlated.

1. (con.)	friable when moist; slightly acid to very slightly acid; 2 to 6 inches thick; clear, abrupt lower boundary.
2. 6-14 inches	Brown (10YR5/3 dry, 10YR3/3 moist) clay loam; strong, medium, subangular, blocky structure; very hard when dry to firm when moist; slightly acid; 6 to 12 inches thick; gradual, wavy lower boundary.
3. 15-32 inches	Dark brown (10YR4/3 dry, 10YR3/3 moist) clay; strong, coarse, subangular, blocky structure; extremely hard when dry to very firm when moist; medium acid; 12 to 24 inches thick; gradual, irregular lower boundary.
4. 33-45 inches	Dark brown (10YR4/3 dry, 10YR3/3 moist) gravelly clay loam; strong, coarse, subangular, blocky structure; very hard when dry to firm when moist; medium acid to strongly acid; 10 to 15 inches thick; diffuse lower boundary.
5. 46- inches	A basic volcanic rock, probably andesite.

Range in characteristics.--The "F" soils are somewhat purplish. Surface colors range from dark brown to dark grayish-brown; subsoil colors are generally dark brown. Subsoil textures range from a clay to a clay loam. The surface may be quite rocky with many boulder outcrops, although generally the soil is fairly rock-free. Depths range from 2 to 5 feet, but generally exceed 3 feet.

Topography.--Slopes are usually flat to gentle or slightly steep. Elevation ranges from 1,500 to 2,500 feet.

Drainage and permeability.--The "F" soils appear to be moderately well-drained and capable of holding large amounts of water.

Vegetation.--Chaparral and hardwood-grass. Garrya fremontii, Rhus diversiloba, Quercus dumosa, Salvia mellifera, and Rhus ovata are common shrubs. Quercus agrifolia is a common hardwood and Umbellularia californica and Juglans californica are sometimes found.

Use.--Watershed protection; browse and cover for wildlife.

Distribution.--Foothills of southern San Gabriel Mountains in Los Angeles County.

Type location.--Sec. 22, T1N, R9W, San Bernardino Meridian. Along Bluebird Truck Trail, 300 feet south of junction of road to Sycamore Flat.

Remarks.--It is unfortunate that this soil is not more prevalent. The "F" series is probably the most fertile soil in the San Dimas area and will probably give the best results in any type of management.

"G" SERIES[9]

The "G" soils are moderately coarse-textured to medium-textured, deep soils developed from diorites, schists, gneiss, and associated rocks at elevations above 4,000 to 4,500 feet. This soil is generally covered by tall dense shrubs and hardwoods. Considerable big-cone Douglas-fir (*Pseudotsuga macrocarpa*) grows on steep colluvial slopes.

A shallow rocky phase of this soil occurs on steep south slopes. Here they closely resemble "A" soils under similar aspect and slope. Somewhat more acid than the "A" soils, they have better structure. However, in spite of many resemblances to "A", these shallow rocky soils are more like the typical "G" soil.

The "G" soils have developed under conditions of low temperatures and fairly high precipitation, much of it as snow. The ground may be frozen for short periods during winter. Moisture may be present in the subsoil throughout the year in deep soils on northern slopes.

These soils range from slightly acid near the surface to medium acid and strongly acid near the parent material. The deeper "G" soils (more than 4 feet) are generally strongly acid below 30 inches.

The "G" soils have moderate, medium, granular structure in the surface horizon to strong, medium, angular, blocky structure in the subsoil. Consistency is soft when dry to very friable when moist near the surface, and hard when dry to friable when moist in the subsoil. Depths range from 1 foot on south-facing rocky slopes to more than 5 feet on north-facing gentle slopes.

Soil profile.--

1. 0-6 inches	Brown (10YR5/3 dry, 10YR3/2 moist) sandy loam; moderate, medium, granular structure; soft when dry to very friable when moist; slightly acid; 2 to 8 inches thick; clear, abrupt lower boundary.
2. 7-12 inches	Light yellowish brown (10YR6/4 dry, 10YR4/4 moist) sandy loam to sandy silt loam; strong, fine, angular, blocky structure; slightly hard when dry to friable when moist; medium acid; 4 to 10 inches thick; gradual, wavy lower boundary.

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[9] Tentative series, not correlated.

3. 13-30 inches Light yellowish brown (10YR6/4 dry, 10YR5/6 moist) gravelly, sandy loam to gravelly silt loam; hard when dry to friable when moist; medium acid to strongly acid; 12 to 24 inches thick; gradual, irregular lower boundary.

4. 31-54 inches Yellowish brown (10YR5/4 dry, 10YR4/6 moist) gravelly, sandy loam to gravelly, sandy silt loam; hard when dry to friable when moist; medium acid to strongly acid; 8 to 20 inches thick; diffuse lower boundary.

5. 55- inches Igneous and metamorphosed rock, mostly schists, diorites, and gneiss.

Range in characteristics.--These soils are usually more than 3 feet deep, sometimes more than 5 feet, measured vertically. On south slopes, "G" soil may be less than 2 feet deep. It is strongly acid to medium acid in the subsoil. Its color is generally a light yellowish brown or yellowish brown, but is very pale brown in some areas. Texture ranges from sandy loam to sandy silt loam. The "G" soils are typically stony and rocky. Colluvial areas on steep slopes are common.

Topography.--Slopes are generally steep to extremely steep. Elevation ranges from 4,000 to over 5,500 feet.

Drainage and permeability.--The "G" soils are well-drained and are capable of retaining large amounts of water.

Vegetation.--Chaparral, hardwood, and conifers. Common shrubs are *Arctostaphylos glauca*, *Ceanothus leucodermis*, *Quercus wislizenii*, *Haploppapus* sp., *Lupinus* sp., *Penstemon* sp., and *Salvia mellifera*. *Quercus chrysolepis* is a common hardwood. *Pseudotsuga macrocarpa*, *Pinus ponderosa* (at Browns Flat), and an occasional *Abies concolor* are the conifers that grow on this soil.

Use.--Watershed protection; browse and cover for wildlife.

Distribution.--Middle elevations in San Gabriel Mountains in Los Angeles County.

Type location.--Sec. 15, T1N, R8W, San Bernardino Meridian. Along road near head of Evey Canyon, 150 feet west of saddle.

Remarks.--Climate and soil depth indicate that this soil would support perennial grasses. Moisture was present at depths of 4 feet on north slopes at an elevation of 4,600 feet. "G" soil in many respects resembles forest soil. Many areas support a commercial stand of conifers. Ponderosa pine site trees measured at Browns Flat show a site index of 150 at 300 years of age on alluvial areas derived from this soil.

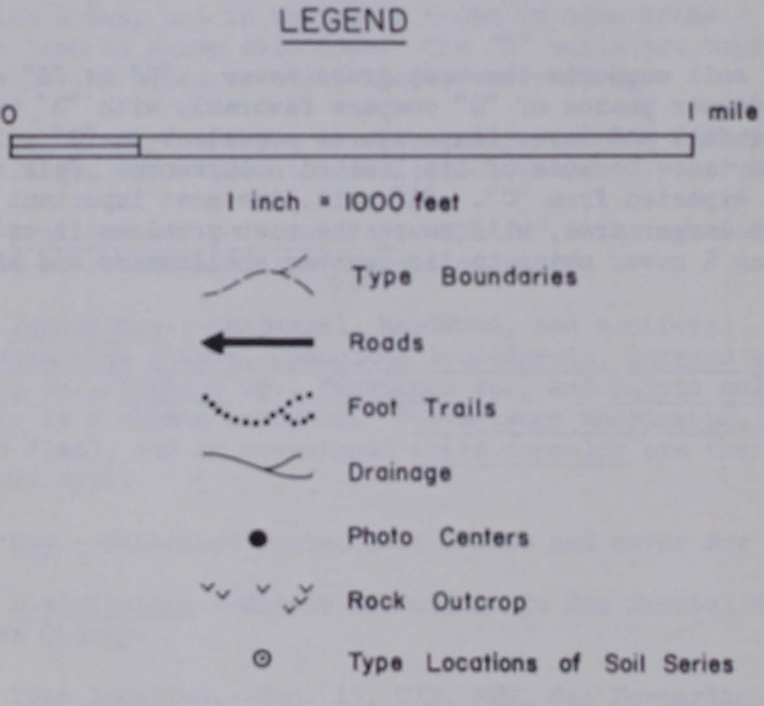
SUMMARY

The soils of the San Dimas Experimental Forest were mapped according to standard soils series criteria. Each of seven series was tentatively designated by a capital letter. The soils of the experimental forest are derived chiefly from a coarse-grained igneous-metamorphic complex of rocks. A few small areas in the southern part developed from fine-grained volcanic rocks.

The largest part of the experimental forest has a very shallow soil cover. This "A" soil intergrades into "G" around 4,000 feet. Above that elevation "G" is the most common soil. Somewhat resembling "A" and often associated with it is "B", a deeper soil that generally occurs on the gentler slopes and has little or no quartz. "C" is commonly found on ridges, surrounded by "A" or "B" on the slopes below. "C" is reddish in color and has some development and varying amounts of quartz. "E" resembles "C", but has less development and is less red. "F" occurs on basalt and differs from all the other soils in its greater depth and degree of development. "D" developed from calcareous tufa deposits found in several parts of the forest.

"F" soil supports the best grass cover. "B" or "E" soils may be rated second. The deeper phases of "G" compare favorably with "B" because of the higher rainfall and lower temperatures prevalent on "G" soils. "D" soil is of little importance because of its limited occurrence. Fair vegetative growth may be expected from "C". "A" soil, the most important series because of its larger area, will cause the most problems in establishing and maintaining a cover owing to its extreme shallowness and the steep slopes.

Figure 1.--Soils of the San Dimas Experimental Forest in southern California were mapped with the aid of aerial photographs.

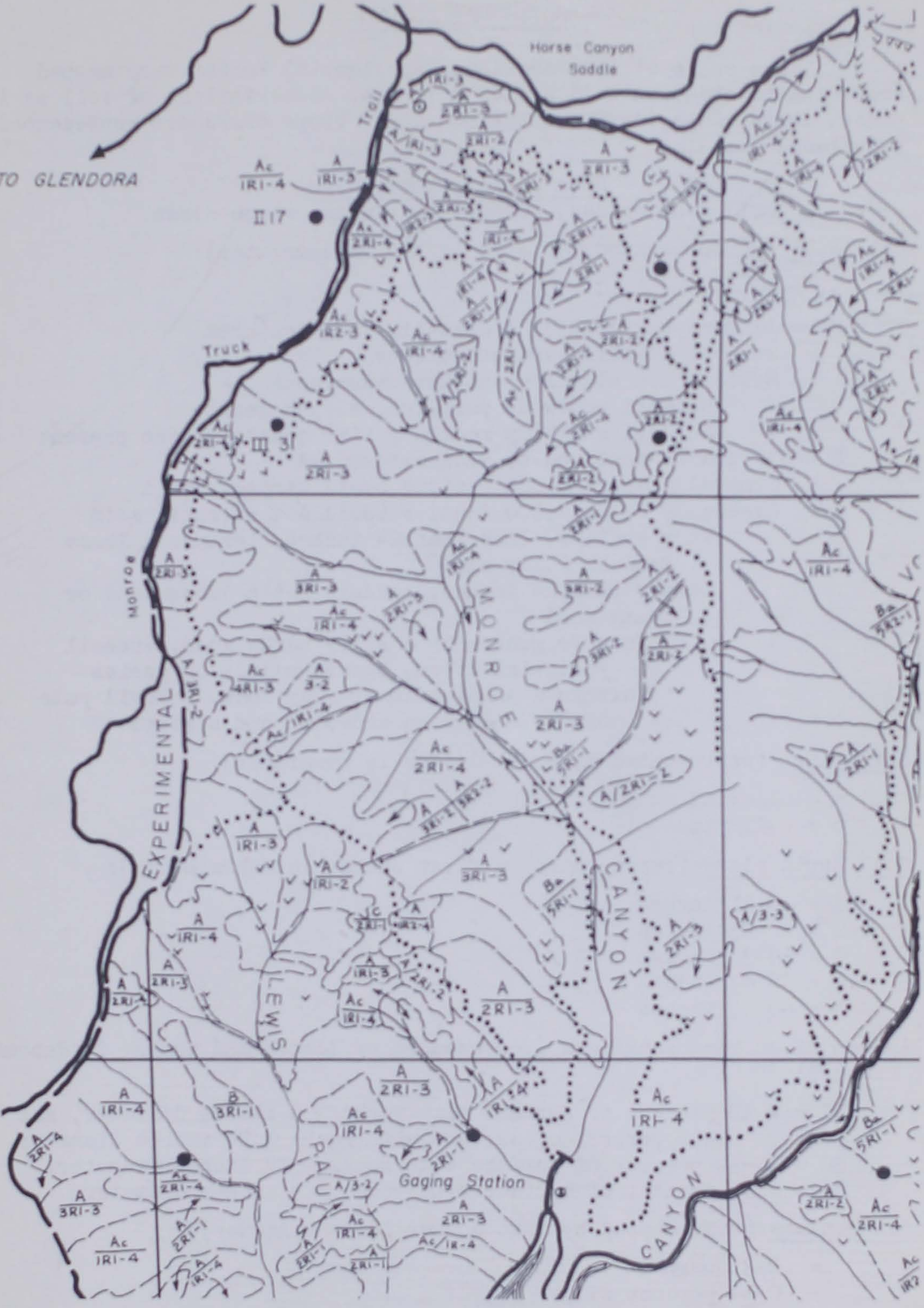

LEGEND
0
1 mile
1 inch = 1000 feet
Type Boundaries
Roads
Foot Trails
Drainage
Photo Centers
Rock Outcrop
Type Locations of Soil Series

Cooperating Agencies

Pacific Southwest Forest and Range Experiment Station, J. Bentley, 1960.
Department of Forestry, University of California, P. Zinke, R. Colwell, 1960.
U.S. Forest Service — California Region, K. Bradshaw, 1960.

Classification and mapping by: J. Crawford, O. Dominguez, 1960.

Map compilation: by: J. Klingensmith, 1960.



TO GLENDORA
Horse Canyon
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Gaging Station
II 17
III 31
Ac/1R1-4
A/1R1-3
A/2R1-3
A/2R1-2
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Ba/5R1-1
A/3R1-3
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A/2R1-3
Ac/1R-4
A/2R1-1
Ba/5R2-1
Ba/5R1-1
A/2R1-2
Ac/2R1-4

SOILS MAP LEGEND

The soils of the San Dimas Experimental Forest were mapped according to standard soil series criteria. Descriptions of soil series, phase, depth class, surface rockiness, and slope class are represented in fractional symbols:

$$\frac{\text{Soil series, soil phase}}{\text{Soil depth class, surface rockiness, slope class}}$$

Soil series (represented by large letter in numerator):

A, B, C, D, E, F, G.

- Subsoil fine-textured or moderately fine-textured
  - Subsoil alkaline and calcareous — D
  - Subsoil not alkaline and not calcareous
    - Subsoil somewhat purplish, slopes gentle — F
    - Subsoil slightly reddish, fine quartz grains present — C
- Subsoil coarse-textured to medium-textured
  - Generally above 4,000 feet, subsoil strongly acid — G
  - Generally below 4,000 feet, subsoil not strongly acid
    - Very shallow, less than 24 inches; texture a loose sand or loamy sand — A
    - Deeper than 24 inches, texture not a loose sand or loamy sand
      - Texture generally a silty sandy loam, subsoil yellowish-brown, occurs mainly on gneiss — B
      - Texture a sandy loam or clay loam, subsoil pale brown, occurs on andesite and schists — E

Soil phase (represented by small letter in numerator):

a = alluvial
c = colluvial

Soil depth class (represented by first number in denominator):

1 = 0-11 inches
2 = 12-23 inches
3 = 24-35 inches
4 = 36-47 inches
5 = 48- inches

Amount of surface rockiness (represented by letter and number in denominator):

R1 = > 10 percent of surface with rocks > 3 inches diameter, and < 10 percent of surface with rocks > 24 inches diameter.
R2 = 10-50 percent of surface with rocks > 24 inches diameter.
R3 = > 50 percent of surface with rocks > 3 inches diameter.

Slope class (represented by last number in denominator):

1 = 0-39 percent
2 = 40-54 percent slope
3 = 55-69 percent slope
4 = 70- percent slope

Crawford, James M., Jr.
1962. Soils of the San Dimas Experimental Forest. U.S.Forest Serv. Pacific SW. Forest & Range Expt. Sta. Misc. Paper 76. 20 pp., illus.

The soils of the San Dimas Experimental Forest in southern California were mapped after a wildfire on July 20, 1960. Seven tentative soil series were mapped with the aid of aerial photographs taken immediately after the fire. A very shallow soil, found chiefly on steep slopes, covers the largest part of the experimental forest. Fairly deep soils occur on gentle to slightly steep slopes. The deep soils of the lower foothills of the San Gabriel Mountains and at elevations above 4,000 feet can support the best vegetative cover.

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